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Early Warning System for Disaster Risk Management

Knowledge brief
On training and capacity building needs

Focus on Landslide Early Warning related to Bhagirathi Valley, Uttarakhand

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We hope that our sincere efforts in bringing forth this document will be useful for training and capacity building for Disaster Risk Reduction and Early Warning Systems.

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Disaster Risk Management Planning and Implementation Support in the Indian Himalayan Region

Contents

1. Introduction

The State of Uttarakhand is prone to landslides (Champati ray et al., 2007). During the monsoon season most hilly regions face major problems due to such events. The cumulative losses incurred by landslides and flash floods far surpass losses caused together by all the other disasters. Lives are lost, transport and supply of essential items are severely affected by landslides and livelihoods are disrupted.

Realizing the hazardous potential of landslides, it is essential to devise proper risk reduction strategies for communities (Samui and Sethi, 2022). Early Warning Systems (EWS) are risk reduction measures, that use integrated communication systems to help communities prepare for and respond to hazardous events. A successful EWS saves lives and jobs, land and infrastructures and supports long-term sustainability (UNISDR, 2012).

Under the auspicious of the Swiss Agency for Development and Cooperation's (SDCs) Global Programme Climate Change and Environment (GPCCE), India is supporting the operationalization of climate change adaptation actions in the mountain states of Himachal Pradesh, Uttarakhand and Sikkim through the phase two of the "Strengthening Climate change Adaptation in Himalayas" (SCA-Himalayas) project that was launched in 2020. The project aims to contribute to the evidence needed to support policy and strategies to strengthen climate resilience of mountain communities. It envisions the transformation of existing capacities in water resource management and Disaster Risk Management (DRM) in mountain ecosystems to design actionable, scalable and replicable strategic interventions to enhance resilience of the local communities. The direct beneficiaries of the project will be the officials and institutions at the sub-national and national level. The project will also inform officials/institutions at the regional level and will lead relevant discussions/processes at global level, while the indirect beneficiaries will be the communities who depend on/are affected by climate sensitive sectors. The project involves the implementation of approaches for Disaster Risk Management that have not been tested in India yet. More precisely, it will support the development of early warning and response systems.

In the State of Uttarakhand, to support state capacities to adapt to climate risk, a rainfall threshold based landslide early warning system was designed for a defined stretch of the Bhagirathi Valley during the first phase of the "Strengthening State Strategies for Climate Actions" (3SCA) project (2016-2019). The objective of the second phase of the project (SCA-Himalayas, 2020-2024) is to validate the aforementioned model, finalise the same by re-calibrating, if required and expand the same to the entire Bhagirathi valley. The project will also develop guidelines for upscaling the model, training modules for capacity building of technical staff from the states across the IHR.

In that respect, one of the activities of this project is to conduct an in-depth assessment of Early

Warning System (EWS) training and capacity building needs. The analysis addresses topics relevant for the EWS design, implementation, and effectiveness, including e.g., allocation of institutional responsibility before and during a warning, use/interpretation of data and scientific advice for decision making, connection between official warning messages and resident's responses, engagement of the media, false-positive and negative alarms. The assessment will thus focus not only on technical but also institutional, social and economic capacities and regulatory aspects relevant for the EWS implementation and long-term maintenance.

In this knowledge brief, capacities necessary for landslide risk management are explored with a focus on designing and implementing an EWS and on achieving a level of preparedness by each person or organization receiving a warning, which allows them to take actions to save their lives or reduce potential impacts. Knowledge, preparedness, technical, response and communication, legal, institutional and economic capacities have been analysed.

2. Background

The State of Uttarakhand is situated in the Himalayan region (northern part of India) and covers an area of 53,483 km^2. It is divided into two major administrative units (Garhwal and Kumaon) with a total of 13 districts, i.e.: Uttarkashi, Dehradun, Haridwar, Tehri, Pauri, Rudraprayag, Chamoli, Bageshwar, Almora, Nainital, Pithoragarh, Champawat and Udham Singh Nagar (Fig. 1).

Uttarakhand is a multi-hazard prone area due to its specific geographical, geological and climatic conditions. The entire Indian Himalaya falls in Zone IV and Zone V of Earthquake Zoning Map of India (IS 1893:2002, Part 1) and in the recent past (1991 and 1999) the State of Uttarakhand has witnessed two moderate magnitude earthquakes with their epicenters at Uttarkashi and Chamoli, respectively. The State however falls in the seismic gap of 1935 and 1905 great earthquakes (Middlemiss, 1910) and has not witnessed a major earthquake for more than 200 years. This enhances seismic risk in the region. Apart from earthquake, the state includes the high mountains and foothills of the Himalaya, resulting in natural hazards such as ice/rock avalanches, rockslide, debris flows, or glacial lake outburst floods (GLOFs; NDMA, 2020). Similarly, the area is affected by tropical monsoons (from April to October) leading to numerous flash floods. These excessive and intensified rainfalls also makes the slopes of the region highly susceptible to landslides, causing every year serious disruptions in the communication and transport routes, as well as destruction of crops, infrastructures and loss of human lives (Munoz-Torrero Manchado et al., 2020). Nowadays, landslide events represent a common and damaging natural hazard in the region (EWS 2019), and the frequency of these events is expected to increase in the future due to climate change (Allen et al., 2017).

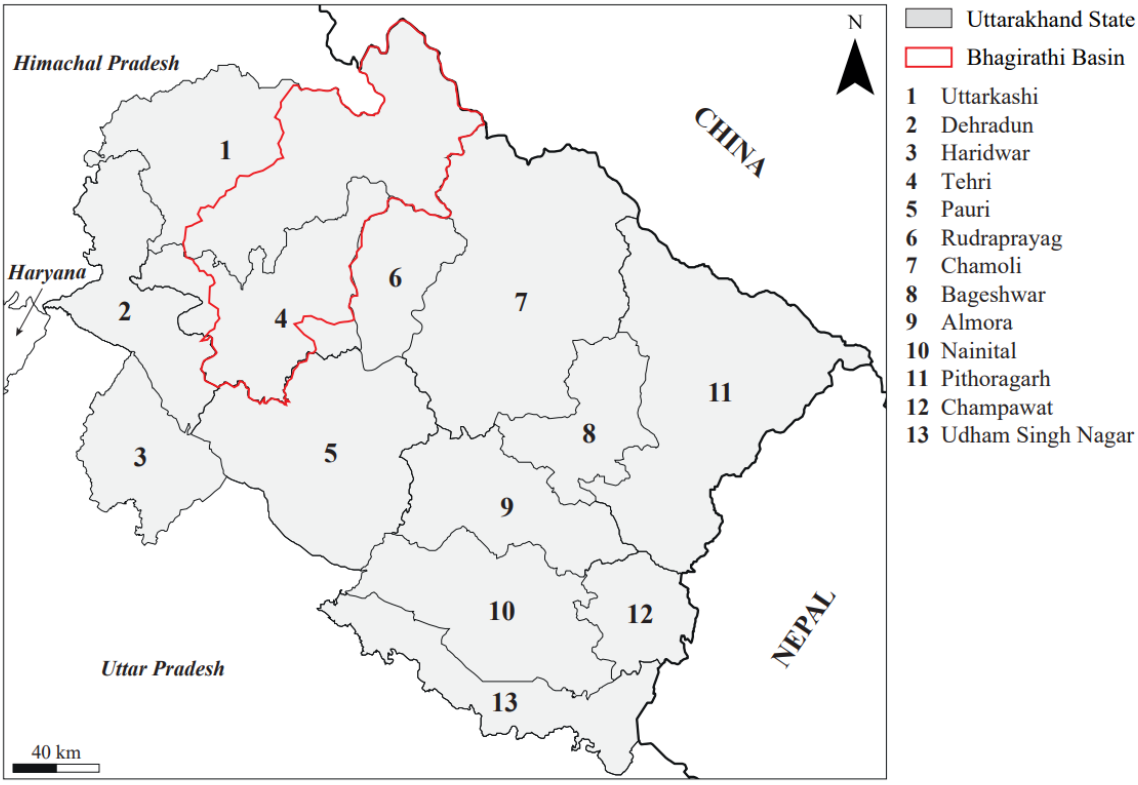

Figure 1: Districts of the State of Uttarakhand, India, own elaboration

3. Landslide susceptibility model - Bhagirathi valley, Uttarakhand, India

Work to date in Uttarakhand conducted under the project Disaster Risk Management Planning and Implementation Support in the Indian Himalayan Region, has focused on the landslide susceptibility model for the entire Bhagirathi valley. This model supposes a model's predictive capacity improvement respect to the current susceptibility model developed during the first phase of the 3SCA project (2016-2019). This new susceptibility model is based on a bivariate statistical analysis and calculating Frequency Ratios (FR) by using a random selection of a new multi-annual (1993-2020) landslide inventory. This new landslide inventory has been created using a semi-automatic identification of landslides with Landsat imagery between 1993-2020 and subsequent systematic manual validation of all events identified. Attributes of the inventory comprises confidence levels to each of the landslides identified (high, medium, low) as well as identified pre-disposing factors and possible triggers (natural [mostly monsoon related], flood related, road construction). In addition, spatio-temporal landslide probability values have been calculated to convert the susceptibility map into hazard maps showing the probability of landsliding per square km for different return periods, i.e., RP (1, 10, 25, 50, 100 years). The database includes precipitation thresholds calculated for each of the 30 different lithologies present in the study area. Finally, in order to assess hotspot areas, all the data values from the above mentioned analyzes (susceptibility, hazard and precipitation thresholds) are spatially related with each of the urban areas within the study area (Fig. 2). These results are stored in vector and raster formats in an ArcGIS geodatabase (.gdb) and organized for display in an Arcmap project (.mxd). In summary the geodatabase comprise the following datasets:

- Identified landslides (point features) of the 4,025 identified landslides between 1993-2020
- Study area (polygon feature). Bhagirathi Valley boundary area and Bhagirathi Valley area bellow 5,000 m asl. The study area polygon feature corresponds to the Bhagirathi watershed area calculated with ArcHydro tools using ALOS Palsar 12.5m DEM
- ALOS Palsar DEM for the study area. Resolution of 12.5m/px
- Lythology polygons (from bhukosh.gsi.gov.in) layer with precipitation thresholds for each lithological layer
- Susceptibility factors raster maps used for the creation of the SDC equivalent susceptibility model and the new UNIGE model: (*i*) Rainfall averaged cumulative monsoon map created from ERA 5 hourly data; (*ii*) Lithology map created from the bhukosh lithology polygons; (*iii*) Lineaments density updated and extended for the entire area from the ones created by SDC; (*iv*) Relative relief, aspect, slope, stream density and elevation calculated from DEM; (*v*) Roads density created from OSM and new roads updated from interpretation and digitizing of recent Google Earth imagery; (*vi*) Land Cover map. New land cover map for the entire area created through supervised classification using Sentinel 2B imagery from 2020
- SDC susceptibility model equivalent by using the same weighted values than in the SDC final report (in raster format) Accuray of 74%
- New landslide susceptibility model using Frequency Ratio weighted values (in raster format) Accuray of 88%
- Hazard (probability) maps for 10, 25, 50 and 100 yrs. return periods (in raster format)
- Urban Areas (polygon features). 6,025 different settlements polygons digitized from Google Earth imagery and with related information about its spatial landslide susceptibility, hazard, and lithological/precipitation thresholds. More information about the development of the landslide susceptibility model are available in Munoz-Torrero Manchado et al., 2020.

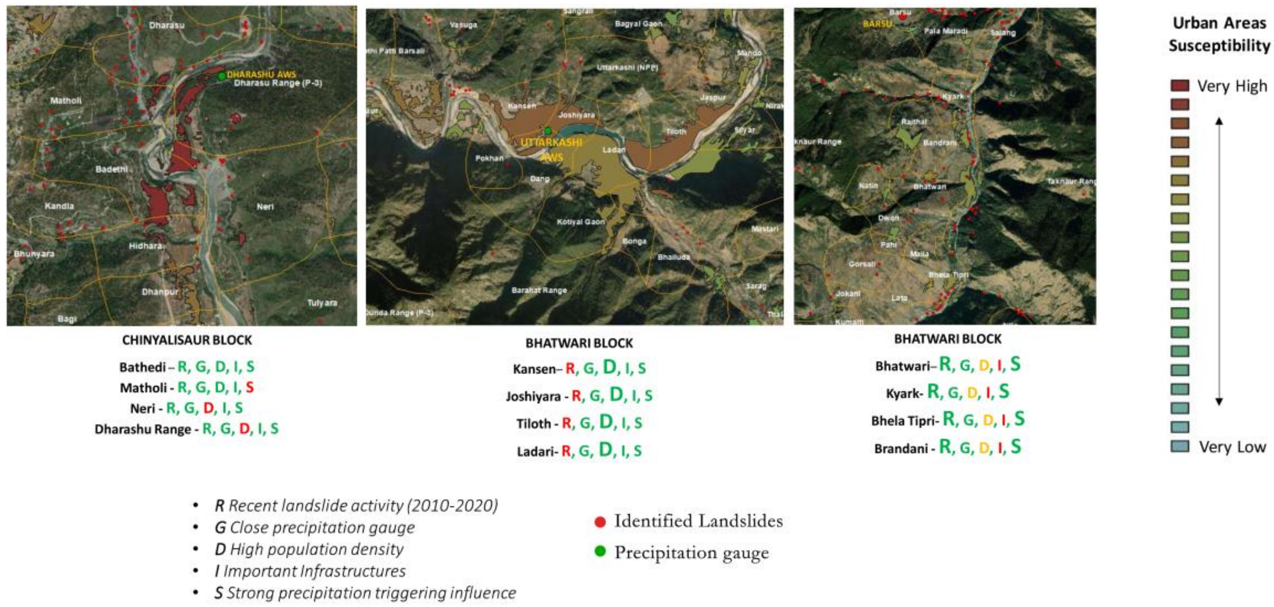

Figure 2: Examples of the identification of different landslide hotspots urban areas based in the new landslides susceptibility model from UNIGE. Additionally, different criteria factors have been taken in account for the selection of this areas as Early Warning System candidates. R- Proximity to recent landslide activity (2010-2020); G- Proximity to a precipitation gauge; H- High population density; I- Important infrastructures in the area (as roads or dams); S- Lithologies with strong precipitation influence. The different colours of the letters represent the degree of influence of each factor for each urban area: Green color: high influence; Orange: moderate influence; Red: Low influence. ©Alberto Muñoz-Torrero Manchado.

4. Disaster risk management in the Bhagirathi valley, Uttarakhand

In the State of Uttarakhand, seismicity, floods and rainfalls are the main triggering factors of landslide events. Yet, anthropic activities such as deforestation, road construction, and additional construction works also strongly affect slope stabilities resulting in an increase of landslide activity. Similarly, climate change is leading to rising temperatures, inducing more frequent heat waves, glacial retreat, permafrost degradation, that affect the hydrogeologic setting of slopes and bedrock stability. It also results in frequent and intense rainfalls, promoting erosion and landslide activities.

Every year, several landslides affect the State of Uttarakhand and major disasters were noticed in the years 1979, 1986, 1998, 2002, 2003, 2004, 2008 and 2009. 29 major landslide events occurred from 1867 to 2013, the year of the Kedarnath disaster, and more recently heavy rainfalls induced a landslide event in Chamoli (Debjani, 2020; Fig. 3).

Numerous transport infrastructure networks and villages are exposed to landslides in the State of Uttarakhand (Fig. 2). For example, the Keadrnath, Badrinath, Haridwar and Yamunotri roads are potentially at risk. Likewise, the Geological Survey of India identified 101 villages vulnerable to landslide (Varghese and Paul, 2013). More than 5,400 causalities result from landslides since 1998 (DRA, 2019) and important costs have been generated for the restoration or repair of infrastructures.

Figure 3: Landslide in Uttarakhand's Chamoli district damages houses - 2020 (Debjani, 2020).

These events also represent a threat for agriculture and hydropower facilities, and even higher exposure may be expected in the future due to further tourist development (unregulated tourist inflow, new transport infrastructure and hotels). For example, the Mussoorie hill station (Dehradun district) is a famous tourist destination highly exposed to landslide hazard.

Given the risk related to landslides, a Disaster Management Plan (DMP) has been developed and updated in 2005. Unfortunately, the Kedarnath tragedy in 2013 highlights that no appropriate land use planning has been made (landslide hazard zonation maps exist, but they are not always integrated in urban and land use plans). Since the tragedy, SDMA has therefore been conducting regular meetings. These meetings are chaired by the Chief Minister (Chairman of SDMA) and every year, District Disaster Management Plans are updated and approved by SDMA.

At present, no landslide early warning system is in place in the state, though few initiatives are being undertaken in Uttarkashi district, one from CBRI Roorkee at Netala in Bhagirathi valley and another in Yamuna Valley by IIT Mandi with support from DDMA, Uttarkashi. In case of an event, people can be alerted and warned by broadcasting through channels such as social media, cell phone, radio, television, loudspeaker and waving a warning flag. But not all communities have mobile coverage and they traditionally refer to early warning signs such as clouds, birds, dry period or announcement of monsoon to detect potential events.

Last, Disaster Mitigation and Management Centre (merged with USDMA) conducted 10 days search, rescue and first aid training at Nyaya Panchyat level from 2010 to 2019. During this period, the

Disaster Mitigation and Management Centre (DMMC) has trained more than 16,000 village volunteers at Panchyat level as first responders by providing training on disaster awareness, first aid and rescue. The information can be accessed development block and district-wise on website (dmmc.uk.gov.in). Similarly, Mahila Mangal Dal (MMD) and Yuva Mangal Dal (YMD) volunteers were trained by USDMA through selected NGOs. At present, 17 Master trainers are available with USDMA. Also, SDMA and DDMAs are organising awareness campaigns through capacity building fund from SDRF. Apart from this, NDMA is also providing assistance to the state for Aapda Mitra training for Disaster Risk Mitigation by preparing volunteers for response and rescue during disaster events.

5. Conceptual framework and methodology

Over the past few decades, guidelines and recommendations for EWS design increasingly encouraged the transition from top-down, command and control style of management to "people centered" approaches (WMO, 2013; UNISDR, 2012; Basher, 2006; Scolobig et al., 2015; Preuner et al., 2017), empowering "individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury and illness, loss of life and damage to property, assets and environment" (WMO, 2018: 3). Some key characteristics of people-centred warning systems include a stronger focus on capacity building, stakeholder engagement and responsibility sharing, enhanced communication supported by technological innovations, and inter-agency collaboration. This results -among others- in a much stronger focus and shifting of resources to the local level, including training, warning awareness and communication activities. Communication and response capability is also one of the 4 key components of EWS, including (UNISDR, 2012; WMO, 2018): (*i*) Risk knowledge (e.g. Are the hazards and vulnerabilities well known? What are the trends of those factors? Are risk maps and data widely available? Do the risk maps consider future scenarios?); (*ii*) Response Capability (Are response plans up to date and regularly tested? Are local response capacities well developed? Are people prepared and ready to react?); (*iii*) Monitoring and Warning Services (e.g. Are the right parameters being monitored? Is there a sound scientific basis? Can accurate and timely warning/alarming be generated?); (*iv*) Dissemination and Communication (e.g. Do warnings and alarms reach all those at risk? Are the warnings and alarms useful, usable and used? Do warnings trigger protective behaviours?) (Fig. 4).

In parallel to become people-centred, those implementing a warning system must know who their audience is and conduct meaningful engagement to understand existing capacities, tools available, level of knowledge, and information requirements for an optimal response (Zhang et al., 2019). Indeed the EWS development is a highly dynamic process, in which success is determined not only by the

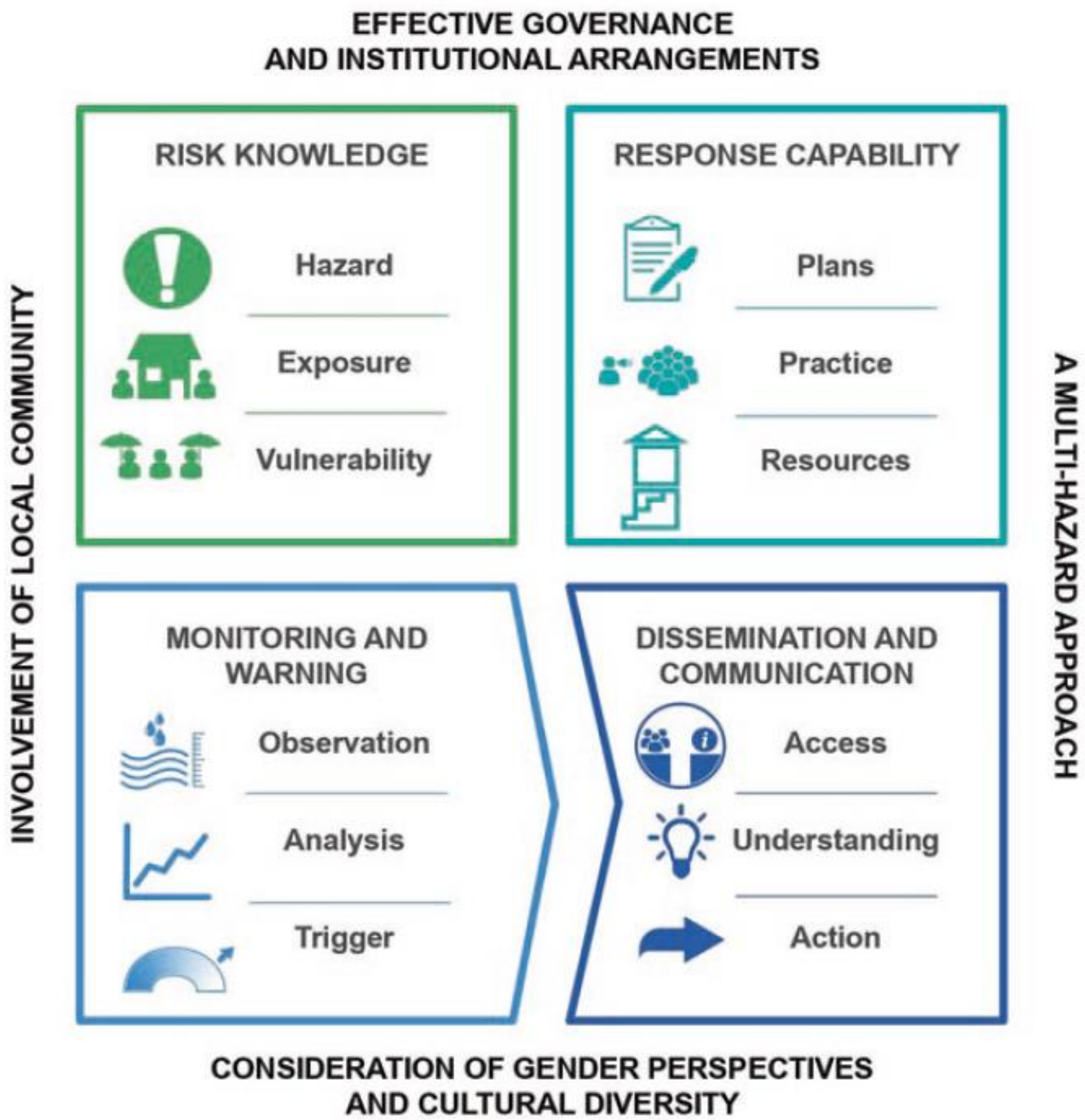

Figure 4: EWS components, based on Golding, 2022

efficiency of the technologies in place and by the availability of accurate data, but also by the capability of the warner to provide 'fit for purpose' information and by the response and adaptive capacity of the receivers.

An effective EWS also critically depends on the creation of good partnerships among those creating, communicating and responding to warnings. Thus, successful EWS operation requires long-term commitment of funding and stakeholder engagement, including local communities, government departments at different levels, private sector, media and regional players.Research increasingly shows that the social components (e.g., community involvement, communication) and the technical aspects of an EWS are of equal importance. However the social aspects are often overlooked (Golding, 2022) and this can cause serious collateral effects. For example in the development of a GLOF EWS project in the tropical Andes of Peru, local inhabitants first requested to remove the EWS and afterwards dismantled the EWS station based on the wrong assumption that the rain gauges and antennas were responsible for the lack of rainfall and drought that hit the region (Huggel et al., 2020). In another EWS project in the Austrian Alps, the community has strongly opposed the EWS substantial investment of tax money to cope with a risk affecting 100 out of 15,000 residents (Preuner et al., 2017).

Based on these and similar cases reported in the Himalayas, Andes and Alps of Europe, it is strongly encouraged to give the social sciences a more prominent role in EWS development (Huggel et al., 2020). Beside the identification of potential intra and inter-community conflicts, the analysis of EWS capacities and social components can considerably contribute also to improve warning communication and dissemination. For example warning communication research highlights that factors that influence receiver's behavioural decision making during a warning include not only message characteristics (e.g., content), channel access and preference (e.g., cell phone, TV, radio) and information sources (e.g., message frequency) but also receiver characteristics (e.g., age, physical abilities), environmental and social cues (e.g., receiving information from family/friends), context (e.g., knowledge on escape road). All these factors need to be taken into account when designing and implementing EWS.

Thus, critical questions are: how to develop dynamic EWS? How to classify and analyze warning capacities? How to identify barriers and leverage on enablers to improve existing capacities? These questions together with a review of the literature on EWS development and warning communication set the stage for the in-depth EWS capacity assessment conceptual framework. Tab. 1 provides an overview and definitions of the key capacities enabling successful EWS, namely: (1) knowledge, (2) technical, (3) economic, (4) response/communication, (5) preparedness, and (6) legal/institutional capacities.

Knowledge	Set of early warning system (EWS) related data, information, but also skills, abilities, and qualifications of EWS target group members
Technical	Technical devices installed (e.g., camera, sensors, installations) to guarantee the observation (monitoring) and warning system functioning and effectiveness
Economic	Financing and economic resources provided by multiple public and private organizations to supper warning system installation and maintenance
Preparedness	Knowledge, skills and abilities necessary for people to know how to behave during a warning, and more generally, an event/disaster
Response and Communication	The set of information sources, channels and tools that allow effective spread of warning messages to the local authorities, emergency managers and residents
Legal and Institutional	The legal and institutional frameworks that allow a good functioning of a warning system

Table 1: Capacities considered in the in-depth assessment framework

In order to analyze these capacities, the study design consisted of two phases: a desk study and semi-structured interviews. The desk study included the collection and analysis of relevant documents, such as newspaper articles, laws, technical reports from the local authorities, disaster management plans, research reports, scientific articles, and books. The semi-structured interviews focused on 3 target groups, i.e., local authorities in charge of communicating warnings to the public, emergency managers and public/community leaders.

The interview protocol has been structured around the six types of capacities presented in Tab. 1. It included a total of 60 open ended questions. For example questions related to knowledge capacities included, e.g., "*Do you think that landslide risk in your area will change in the future, and what would be the main driver of this change?*". Technical capacities have been assessed through several questions addressed to local authorities and emergency managers including, e.g., "*How good is the mobile network coverage (type of signal, provider)?*". Communication capacities have been analyzed with questions such as "*Are warnings generally understood by people and useful for them?*" or "*What type of channels and messages are most effective?*". Legal and institutional capacities include questions as, "*Are there any legal issues related to evacuations?*". The protocol ended by asking interviewees some reflections about key strengths and weaknesses of existing warning systems. The interview protocol is available in Annex A.

Overall the methodology included: (*i*) a desk-based review focused on disaster risk management for the Bhagirathi valley, Uttarakhand; (*ii*) consultation with 59 stakeholders including targeted semi-structured interviews (face-to-face), one workshop and one online meeting (presentation on draft knowledge brief on EWS training and capacity-building needs). The 59 consulted stakeholders included: a) 41 attending the project inception workshop on September 09, 2021 (for the minutes see Annex B); b) 10 attending the online meeting for presentation of draft knowledge brief on September 27, 2022 (for the minutes see Annex C); c) 8 interviewees contacted in April, 2022. These stakeholders represented different sectors and administrative levels, as well as non-governmental entities involved in the disaster risk management, including e.g., local residents of Uttarkashi (mostly men), the State Emergency Operation Centre, the District Disaster Management Officer, a consultant from District Disaster Management Authority, and the Executive Director of Uttarakhand State Disaster Management Authority (see Annex D for a list of the stakeholders involved).

In the following section, we provide an overview of the key results of the EWS capacities and needs assessment in Bhagirathi valley, Uttarakhand. We report on the stakeholder's expected challenges in the design, implementation, operation and circumstances around the setting up of an EWS for landslides. Text in italics corresponds to interview excerpts.

6. Findings

Landslides are common events in the State of Uttarakhand and occur every year triggered by intense rainfalls and cloudbursts (NDMA, 2019). For example, the 2013 cloudburst event induced numerous problems in almost every part of Uttarakhand. In general, local administration as well as local people are quite aware of active landslide zones (many places in Uttarkashi such as Dunda, Tambakhani, or Pata village are prone to landslides) and ensure measures to avoid losses due to their reactivation. In that respect, known landslide-prone areas are potentially less at risk than the new emerging ones.

Yet, in practice, landslide frequency has changed over the last ten years and is likely to be increasing due to climate change (changing pattern of monsoon rains). Even more alarming, landslides are no longer events of only monsoon seasons since they also occurred in dry periods (as a result of soil moisture variations in high altitude elevations or road cutting). Consequently, landslide risk is becoming increasingly important as (1) mass movements are becoming more active, (2) landslide events remain challenging to predict and (3) also because of higher damage potential (global population and infrastructure increase; NDMA, 2019).

Furthermore, landslides are a main concern for residents in the Indian Himalayan Region. First, landslide events are a major threat for human life including, e.g., local population, tourists, workers, school-going children, etc. (NDMA, 2019). The Bhagirathi valley was further selected by the project given the large number of tourist passing through this region every year. Secondly, these events can lead to the near-total destruction or obstruction of transportation network resulting in road blockages from few hours to several days given the intensity of the event and its location. For example, the road to Harshil remained closed for 90 days after an extreme event in 2013. Landslide events therefore pose a threat for transportation corridors (Debjani, 2020), and more broadly can also affect houses (Fig. 3, infrastructure, animal life (cattle/livestock) and forest covers (ecological impacts). Similarly, landslides affect arable lands thus decreasing the surface areas dedicated to agriculture practices. In that specific case, no alternative has been proposed, especially since local population cannot exploit forested areas due to Eco-Sensitive Zone regulations (ZMP, 2018). Last, debris from landslides can be re-mobilized in heavy rainfall instances, block stream flows resulting in overflowing of stream into adjacent areas. This risk of process chains and secondary processes will be even more important in the next decades since debris are not allowed to be removed from the river-bed as it is an eco-sensitive region (ZMP, 2018).

To be well informed of potential landslide events, 18 automatic weather stations from different agencies (including USDMA, IMD, SDC and THD India Ltd) have been installed at different locations in the State (should be Bhagirathi valley; Fig. 5) with the objective to relay information on heavy rainfalls with low lying villages. At the State scale, more than 150 AWS are operational. Such an approach is feasible as local people widely use cell phones so that information can be shared using mobile communication (SMS, social networks, etc.). But this type of communication results in some weaknesses related for example to the mobile network coverage that has an actual average efficiency.

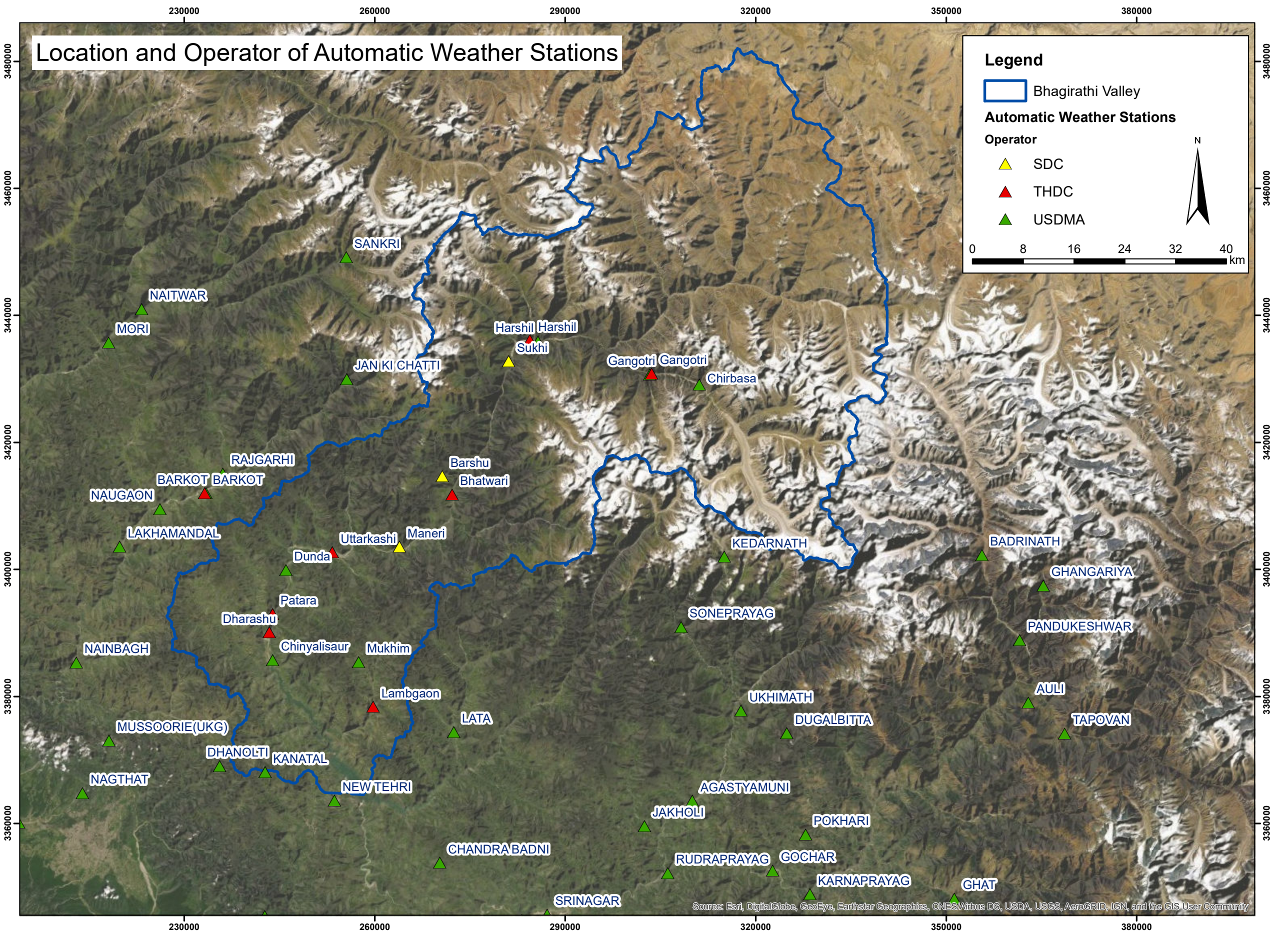

Figure 5: AWS Location Map of Uttarkashi District. ©Geotest

Even if automatic weather stations promote a better anticipation of landslide events, landslide technical devices must be implemented in Uttarakhand in order (1) to monitor hazardous areas and (2) to alert communities when imminent threats are detected. In parallel of the development and installation of technical devices, efforts must also be dedicated in setting up a communication plan for alarming population in case of an event. Indeed to date, no landslide EWS are implemented in Uttarakhand while alarming are essential for helping community to respond effectively and for saving lives. According to interviewees, digital display boards, sirens, loudspeakers and local radio appear the most effective and efficient means to communicate about landslides. Yet, such devices do not necessarily cover the whole area at risk so that mobile communication (SMS announcement - as for heavy rain forecasts) and internet (social media, WhatsApp, etc.) must also be promoted to reach as many residents as possible.

Currently, efforts are being made as demonstrated at Netala where a monitoring system and EWS is under development (primary phase - CBRI and IIT Roorkee initiative). Unfortunately, communities are poorly involved in the EWS implementation processes and too few initiatives (e.g., participatory process) to increase community preparedness and landslide/EWS knowledge have been conducted. Consequently, vandalism or robbery can appear due to negative perceptions of warning systems. In that respect, the community needs to be informed about the importance of the equipment being installed including the benefits. At the technological level the installed equipment should discourage robbery (e.g., webcams, fencing, installation in safe places like government premises/buildings, monitored by some local person, etc.).

In case of a landslide, the local Pradan will be the key focal point for disaster related contingencies and it can refer to the DRM plan to manage the crisis. Yet, in practice, the near total absence of DRM dissemination among communities is a main issue for the DRM plan implementation. Similarly, communities have limited knowledge of solutions and traditionally use their indigenous knowledge or their common sense to respond. Moreover, communities can encounter difficulties when coordinating with the emergency control room at the district headquarters (aims at collecting information from various agencies as well as calls from the villages round the clock) and the emergency management of the Disaster Management Department (temporary staff) due to (1) the scarcity of essential tools for rescue operation such as radios or alternative wireless communications and (2) the frequent telecommunication failures.

Given the magnitude of the event and the impacted elements at risk, emergency services such as the platoon of the State Disaster Response Force (for general areas, stationed during monsoon months) and the paramilitary force (ITBP) can be deployed on the field. Past events demonstrated that army camps are of great help but they are rapidly overburdened. In that respect, basic training in search and rescue are given in some villages (by village members) to better overcome emergency situations.

Finally, interviewees maintain that communities are often unaware of hazards and associated risks so that they disregard the Departmental Disaster Management Plan. Unfortunately, evacuation plans are part of the DRM plan and communities are therefore not well aware also about evacuation procedures. Similarly, too few shelters exist (schools are being used as shelters) and often residents do not consider them as safe.

7. Addressing local needs to improve EWS capacities

In this section, we provide an overview of the key results of the EWS capacities and needs assessment in Bhagirathi valley, Uttarakhand. Literature and scientific reports, consultation workshop (Annex B) as well as interviews and stakeholder consultations provided the background.

7.1 Knowledge capacities

7.1.1 Improve landslide awareness

Interviewees maintain that local/indigenous knowledge is the main source of information for communities. In parallel, interviewees also maintain that "*no risk perception studies have been conducted in the communities*" (int. 1, 2, 3, 7 community) and "*landslide hazard zonation maps received from various research and academic institutions have little utility. The scale of these products is also to coarse to be useful for practical purposes*" (int. 8 State level officials). Consequently, there is a crucial need to reinforce the scientific knowledge about local landslide phenomena as well as to communicate the key aspects of such events to make people aware about risk levels. "*Such insights can help in greatly reducing the menace of landslides*" (int. 8 State level officials). Similarly, training of officials from line departments, involved in landslide risk management like, officials from Public Works Department, Irrigation department, Geology and Mining department along with technical persons from DDMA, needs to be undertaken on different aspects like monitoring of slopes that pose risk, developing and maintaining an event register for landslides.

7.1.2 Improve EWS awareness

According to the interviewees, another weakness seems to result from the absence of communication regarding the importance of EWS. Indeed, the residents are poorly involved in the warning system implementation and too few initiatives to increase EWS knowledge have been conducted so far. Yet, in practice, "*the community needs to know the importance of the system, to be acquainted with EWS instruments. Community groups can also contribute to monitoring*" (int. 8 State level officials). Engaging with the local population as close as possible is also considered a priority (e.g., sharing information about the levels of warning, understanding of warning protocols, effective warning response and behavioural recommendations, etc.). In the past, the Disaster Mitigation and Management Centre (DMMC) has trained more than 16,000 village volunteers at Panchyat level as first responders by providing training on disaster awareness, first aid and rescue. Refresher courses and updates need to be organised for these village volunteers/anganwadi workers/gram prahari/mahila mangal dal/yuva mangal dal with inclusion of EWS (aware of the early signs of slope instability, understanding sign boards, sirens and SMS, time between an event and a warning, translation of warnings into action) and landslide EWS modules in all awareness programs. A key role should be played by the State Disaster Management

Authority (SDMA) and the District Disaster Management Authorities (DDMAs).

7.1.3 Dissemination of DRM and evacuation plans

An accurate communication of the key points in the Disaster Risk Management and evacuation plans is also considered a priority. A better information sharing should therefore be promoted so that people could be educated with all the information related to disaster management as a whole.

7.2 Preparedness capacities

7.2.1 Improve the response during a warning

Knowledge, skills and abilities necessary for people to know how to behave during a warning/alarm, and more generally, an event/disaster, are not well developed. Interviewees mentioned the invaluable assistance of the army team during crisis situations but also highlighted that the latter can be rapidly overwhelmed during an event. "*Training programs, rescue techniques, first-aid and improvisation techniques*" (int. 7 community) should therefore be proposed in every village to educate communities to basic first aids and rescue processes. In that respect, pressures on emergency services could be alleviated and the crisis could be partially managed through the community. Such trainings are even more relevant because it can be challenging or time consuming for emergency services to reach impacted zones (remote areas, roads blocked, etc.). Similarly, warning/alerts received by the state government are disseminated by SDMA/DDMA through State Emergency Operation Centre/District Emergency Operation Centres. Response to any emergency is done by activating Incident Response System (IRS). Staff responsible for the dissemination of warnings at emergency operation centers and officials deputed at various positions of IRS need to understand the warning protocols and respond accordingly, so comprehensive training on warning protocols including Common Alerting Protocol (CAP) is required for SEOC, DEOC and IRS staff.

7.3 Technical capacities

7.3.1 Elaborate a landslide surveillance network

EWS is considered a priority to increase risk preparedness, while monitoring, warning and alarming are central elements of an EWS. "*Monitoring instruments and technical measurement tools of critical slopes such as Varunavat Parvat and Uttarkashi*" (int. 8 State level officials) must be set up to detect hazards so that timely warnings can be issued. Unfortunately, there are currently no sounds, no sensors, or sustainable data management system allowing real time communication and information on landslide events in Uttarakhand. To this aim, it seems crucial (*i*) to identify places where technical devices could be installed for monitoring and warning/alarming as well as (*ii*) to improve their design so that electric black outs and robbery/vandalism would be avoided. For sustainability of these systems, a pool of technical experts needs also to be created for monitoring these equipments, understanding and analysing warnings generated by them. The implementing agencies need to train the staff from the concerned departments like Geology and Mining, PWD and DDMA on various technical aspects related to the operation and maintenance of instruments in addition to providing remote support for technical queries. One workshop's participant mentioned that landslides are now an "*all season*" phenomenon and are not restricted to monsoon season only. Moreover some landslides have a sudden outbreak with no lead time for warning. Thus, he further suggested that training modules/curricula must include local hazard scenarios and traditional coping practices.

7.3.2 Improve coverage network

Interviewees maintain that one main weakness at the State of Uttarakhand results from communication difficulties ("*average network coverage*"; int. 5, 6 local authority). First of all, it is essential to ensure an effective communication network to support constant exchange of information between the impacted communities and the emergency service. In areas where the network coverage is limited, basic disaster management tools -like sirens- are provided but communities often still need to be trained for the use of such equipment's or protocols. Ensuring appropriate and efficient use of the available tools is thus a priority. Last, some areas preclude reliable communication (shadow areas) and therefore require to be identified so that such difficulty can be overcome through an adapted communication system (e.g., emerging technologies may be useful to cover these areas).

7.4 Response and communication capacities

7.4.1 Define a communication strategy

As highlighted by a State official during one of the workshops: "*Warning generation is important but dissemination of warning is as important as generation*". Thus, it is important to train communities to translate warnings into action. There is a need to better understand how to ensure that each person is in the capacity to respond to warnings. To this aim, documenting traditional coping mechanisms and EWS best practices is recommended (e.g. data can be collected by means of surveys in communities exposed to landslide risk). Some examples of practices of low cost community-based EWS systems are annexed in this knowledge brief (see Annex E). Based on the interview results, "the installation of an early warning system is necessary and it would help in warning tourists passing through landslide zone" (int. 1 community). In practice, several type of communication tools could be adopted to disseminate information about critical situations. Amongst all, sirens seems to be the most efficient and reliable ways of communicating. Unfortunately, such alarming does not cover the whole at risk area so that some people will not promptly receive the information. On the contrary, almost all publics are connected/actively interacting via cell phones, social media or similar (SMS, WhatsApp). In that respect, mobile phone messages or applications are of great interest since they can provide landslide early warning notifications to different target groups. One proposed solution would be to use both sirens and mobile communications (e.g., "*sirens installed at National Highway at Netala to warn tourists and locals along with SMS to the local community living nearby landslide zone*"; int. 2 community) so that "*landslide warning could be regional or location specific*". This is all the more important than the Bhagirathi valley is a famous tourist and pilgrimage area, therefore requiring to identify strategies to warn these vulnerable population groups. Finally, it also seems crucial to consider traditional knowledge, customary and rituals in the EWS planning and communication strategy, to be suitably adapted to each community and ensure that each person is in the capacity to respond to warnings.

7.5 Legal and institutional capacities

7.5.1 Strengthen human resources

One of the main institutional barriers is lack of human resources for disaster risk management at the local level. Staff is often hired with short term contracts and the high level of turn over does not support EWS knowledge improvement.

7.5.2 Define EWS installation permissions

Interview results highlighted the crucial need to clarify (1) if formal permission for the installation of EWS is needed, and (2) where/how could such a permission be obtained (in case needed). In greater details, interviewees mentioned for example that: (*i*) "*such permission should not be required if EWS instruments are installed on private property*"; (*ii*) "*such kind of permissions can be provided by Uttarakhand State Disaster Management Authority (USDMA) or from District Administration, Revenue and Forest Department*" (int. 4, 5 State level officials/local authority); (*iii*) "permission has to be sought from the organization that owns the land/premises where the device is planned to be installed" (int.

8 State level officials). Generally, it is suggested to install such devices on public land. Moreover to ensure the effectiveness of the legal framework for EWS installation (and thus avoid potential future conflicts) it is necessary to clearly define financial, data and installation responsibilities.

7.5.3 Define appropriate responses against vandalism

Vandalism acts cannot be disregarded in the State of Uttarakhand. Such actions result from (1) the lack of awareness on the importance and benefits of the equipment being installed and (2) the absence of "*punitive measures for non-compliance and incentives for compliance*" (int. 8 State level officials). Based on Disaster Management Act 2005, theft or damage to EWS can be condemned ("*routine charges to public property*"; int. 8 State level officials) to limit vandalism acts. "*The DDMA and/or Revenue Department could be in charge of the sanctions*" (int. 5 local authority).

7.6 Economic capacities

Concerning economic capacities "*finance is not an issue and can be raised through the mitigation fund of State government and external funding agency*" (int. 6 local authority). But economic resources are often dedicated to EWS implementation and mitigation actions at the expense of training programs or equipments. A better distribution of fundings should therefore be promoted to allow effective EWS implementation (e.g., "*increase fundings for more researches on landslide issues in universities and research centers*"; int. 4 State level officials).

Last, the State Disaster Response Fund has provisions for meeting expenditure on training and capacity building programs up to a specific limit. This could be used for meeting the training and capacity building needs of departmental officers and communities. In addition to this, NDMA and other external sources can be explored for this purpose.

7.7 Strengths and weaknesses evaluation

During the stakeholder consultations, strengths and weaknesses in the existing warning value chain have been evaluated. Information about training needs have also been collected. Table 2 provides a summary of the key inputs provided by the interviewees.

Strengths	Weaknesses
• Existence of an Emergency Control room • Cooperation with the State Disaster Response Force • Existence of a Departmental Disaster Management Plan • Presence of several automatic weather stations • Training focused on basic first aids and rescue processes	• Poor coverage network • Lack of landslide technical devices • Lack of communication plan • Absence of tools for rescue operations • Lack of shelters • Limited scientific background • Low public participation in DRM and EWS • Lack of human resources for DRM
Training needs	
For communities • Community awareness raising • Training focused on EWS *For practitioners (e.g., emergency managers)* • Training focused on disaster related contingencies • DRM dissemination • Coordination exercises with the Emergency Control room of the Disaster Management Department • Training focus on EWS proposal development, including economic and institutional capacities	

Table 2: Strengths, weaknesses, and training needs

8. Recommendations

In this knowledge-brief, we explored the capacities necessary for designing and implementing an EWS and for achieving a level of preparedness by each person or organization receiving a warning, that allows them to take actions to save their lives or reduce potential impacts. The analysis builds on the consultation with 59 stakeholders including targeted semi-structured interviews (face-to-face) and one workshop. Table 3 provides a summary of recommendations based on the results presented in Section 7.

Type of capacity	Synergies with ongoing activities	Recommandations
Knowledge capacities		
Improve landslide awareness	SDMA and DDMAs are organizing awareness campaigns using the SDRF capacity building fund	Exercises and practical training sessions on hazard assessment in the field; village disaster management training; awareness programs; video/audio documentaries; meetings with communities/youths; scientific training initiatives for risk and emergency managers; public information campaigns; capacity building programs for local villagers; training of policy makers to take slope management into consideration in urban and economic development planning and decide about infrastructure development accordingly
Improve EWS awareness		Training on landslide warning generation models; awareness programs to be organized before EWS installation; video/audio documentaries; exercise session for understanding of warning protocols/ways to respond to a warning issued.
Disseminate DRM and evacuation plans	Extensive volunteer and community training conducted by USDMA	Proper dissemination of DRM and evacuation plans
Preparedness capacities		
Improve the response during a warning	Synergies with the platoon of the State Disaster Response Force and the paramilitary force; NDMA is providing assistance for Aapda Mitra training for Disaster Risk Mitigation by preparing volunteers for response and rescue during disaster events	Training about response after siren activation; training programs, rescue techniques, first-aid
Technical capacities		
Develop a landslide surveillance network	18 automatic weather stations have been installed at different locations in the State to provide information on heavy rainfalls; more than 150 AWS are operational	Sound and sustainable monitoring and warning system, data management system should be promoted (RADAR based instruments, InSAR); promote solar panels and batteries for energy generation and storage in case of blackouts; inputs on the type of systems available and the best suitable one for Bhagirathi valley
Improve coverage network		Better use of communication channels; reinforce network coverage; warning dissemination system needs to be strengthened
Response and communication capacities		
Warning communication strategy	Synergies with the emergency control room and the emergency management of the Disaster Management Department	Training on warning protocols; training on siren protocols, and preparedness; training on communication protocol; community training programs on risk communication
Legal and institutional capacities		
Strengthen human resources		Promote long-term or permanent staff in the Disaster Management Department to strengthen their experience in managing risk
Define EWS installation permissions	Building on existing DRM regulatory framework and guidelines	Clarify permission allotments and procurement processes; financial and system responsibility
Define appropriate responses against vandalism		Define punitive measures in case of vandalism
Economic capacities		
Better funding distribution for different EWS components		

Table 3: Recommendations

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Annexes

A Protocol

KNOWLEDGE CAPACITIES

Questions for	
All target groups	What are the areas that could be affected in case of a landslide? What are the main causes of landslides in ___ selected hotspot area? What are the 3 elements at risk that you would like to protect from landslide in ___ selected hotspot area? Do you think that landslide risk in your area will change in the future and what would be the main driver of this change? Do you know of the existence of a Disaster Management Plan (DMP)? Do you have access to it? Are there any issues hindering the plan implementation? Has the DMP been revised since the latest events in the area? What would be the key components of a warning system for landslide risk in ___ selected hotspot area? How can knowledge capacities for landslide warning system development be improved? What knowledge/capacities are priority? What type of training is needed to increase your knowledge about preparing and responding to landslide?

TECHNICAL CAPACITIES

Questions for	
Local authorities and emergency managers	Could technical devices (terrestrial installations) be installed on e.g., : i) outcrops; ii) infrastructures (e.g., bridges)? If yes, where (map, photos)? Are there existing installation sites that could be further developed and/or new installation sites that have been foreseen? If yes, can details (e.g., photos, reports, maps) be provided? Specific questions may include: What is the slope-exposition of those potential installation sites in ___ selected hotspot area? Are there already webcams in place in ___ selected hotspot area? If yes, who has access to these webcams and can new ones be installed? How good is the mobile network coverage (type of signal, provider)? Can we get electricity for technical installations? What are the options for (electric) energy generation during black outs? Do you think that technical devices installed (camera, sensors, installations) for a warning system may be stolen/damaged? How could robbery/vandalism be avoided? How would a closing of a road/evacuation of a settlement impact daily life? Does the capacity exist to install the technical components of such an EWS? Who could do that (company, institution, etc.)? More generally, how can technical capacities for landslide warning system development be improved? What technical devices are a priority? What type of training (if any) is needed in relation to EWS technical capacities?

ECONOMIC CAPACITIES

Questions for	
Local authorities and emergency managers	Is funding available for EWS implementation and maintenance at local level? Who should be responsible for it? Is funding available for new mitigation measures/complementary to EWS? How can economic capacities for landslide warning system development be improved? What capacities are a priority? What type of support to leverage or apply for funding would be needed?

PREPAREDNESS CAPACITIES

Questions for	
All target groups	Do you think that communities/residents have sufficient capacities to prepare and for natural calamities (landslide)? Why? What capacities need to be developed? What are the main lessons learnt from recent/past events for preparedness? Are communities involved in the design of warning systems? Are there initiatives already in place (e.g., participatory community mapping or planning) to increase community preparedness and EWS knowledge? Are there any local conflicts (e.g., about funding, type of technical measures to be implemented, etc.) hindering the adoption of a warning system? How can preparedness capacities for landslide warning system development be improved? What are the priorities? What type of training (if any) is needed to improve preparedness capacities?
Emergency managers	To our knowledge, there is an evacuation plan available for this location? Based on your experience, does the evacuation plan work effectively? Are escape routes and evacuation shelters known by all the population and accessible to everyone even during extreme landslide activity? What should change?
Public/ community leaders	Have risk perception or preparedness studies been conducted in the community and what were the main learnings? Would citizen science initiatives (e.g. to monitor water levels) work?

COMMUNICATION CAPACITIES

Questions for	
All target groups	Did you receive a warning for a natural calamity in the past? If yes, which calamity? If so, who provided the warning? Through which channel (mobile phone, siren)? Did you understand it well? What can be improved? Are warnings generally understood by people and useful for them? What type of channels and messages are most effective? Is the local population connected/actively interacting via cell phones, social media or similar? If so, who is connected? What needs to change? Is any environmental monitoring implemented? If so, do thresholds for alarming exist (based on, for example, existing discharge values)? Do alerts (such as sirens, signal light, cell phone communication or oral information) cover the whole at-risk area? Does a procedure of cancellation/"all clear" alarm of the warning levels exist? Are false or missed alarms frequent? Are they decreasing response effectiveness? Overall, do you think that warning communication for natural calamities is effective? What should change? How can communication capacities for landslide warning system development be improved? What capacities are priority? What type of training (if any) is needed to improve communication capacities?
Public/ community leaders	Is the information about an ongoing event received by all sub-groups (women, children, elderly, tourists, school teachers, etc.)? Are the warnings understood by all?

LEGAL AND INSTITUTIONAL CAPACITIES

Questions for	
Local authorities and emergency managers	Who/which authority would be in charge of operating and maintaining and EWS? Are there any legal issues related to evacuations? Are building constraints and land use related hazard zones respected? In case of a disaster, who validates the crisis situation and activates the emergency plan? Are the present institutional and legal frameworks working effectively? What needs to change? Who is responsible in case of false or missed alarms? Are there any economic consequences for local authorities in case of missed or false alarms? Who declares the end of the disaster and on the basis of what information/data? How can legal and institutional capacities for landslide warning system development be improved? What type of training (if any) is needed to improve e.g. knowledge about legal and institutional capacities?

SUMMARY AND CONCLUSIONS

We have discussed the multiple capacities needed for effective functioning of EWS.
To conclude:

- What are the main (max 3) strengths and weaknesses of present warning systems?
- What capacities need to be more developed in ____ selected hotspot areas?
- What training is most needed to develop these capacities?

B Minutes of the Consultation Workshop, Sep 09, 2021

Rainfall threshold-based landslide forecast model for Bhagirathi valley, Uttarakhand, India

Date: 9 September 2021
Time: 11.00 am -13.00 pm India time/ 07.30 am - 09.30 am Swiss time

The Swiss Agency for Development and Cooperation's (SDC) Global Programme Climate Change and Environment (GPCCE) India is supporting the operationalization of climate change adaptation actions in the mountain states of Uttarakhand, Sikkim and Kullu (Himachal Pradesh) through the "Strengthening Climate Change Adaptation in Himalayas (SCA-Himalayas)" project. As part of the project a workshop was organized for Uttarakhand focused on the implementation of a landslide Early Warning System (EWS) and disaster risk management. About 45 participants attended the workshop.

Summary of Key Points

1. Ms. Corrine Demenge, Head of Swiss Cooperation Office in India welcomed the participants to the Consultation Workshop for Early Warning and Response System for Landslides and GLOF for Bhagirathi Valley in Uttarakhand jointly organized by Uttarakhand State Disaster Management Authority (USDMA), Government of Uttarakhand and the Swiss Agency for Development and Cooperation (SDC). In her welcome remarks, she briefed on the Swiss experience in mountain ecosystems in India and globally. She provided background information on several key aspects related to the SCA-Himalayas project. She further explained the objective of this consultation workshop for designing and establishing a Landslide EWS and identifying stakeholders for needs assessment for training and capacity building activities.
2. Dr. Piyoosh Rautela, Executive Director of USDMA, in his opening remark highlighted the several landslide and flash flood events in the States starting from 18th century (1880-2021), which have increased in frequency and intensity due to high vulnerability and climate change till recently. He gave an insight of the starting of the Disaster Management Committee in the state after the 1978 flood disaster in Dhauli- Ganga. He emphasized the importance on regular monitoring of the EWS to know the efficiency and suggested that reports on the disaster should be prepared at an early stage to reduce the post disaster stress. Dr. Rautela also emphasized the need to improve the InSAR based landslide assessment and rockfall modelling.
3. Ms. Divya Sharma presented an overview of the SDC's Strengthening Climate Change Adaptation in the Himalayas (SCA-Himalaya) project. Ms. Sharma stated that the SCA-Himalayas project addresses the issue related to climate-resilient management of disaster risks, for which it is focusing on glacial lake outburst flood (GLOF) and landslide early warning system in Sikkim, Uttarakhand and Himachal Pradesh. Other key component of the project is to enhance the technical and institutional capacity of the national and state level institutions. In the first phase of the project, Swiss experts had contributed to the development of the National Guidelines for Management of GLOF risks that was released by the National Disaster Management Authority (NDMA) in 2020. She stated that the SCA-Himalayas project is designed to bring about large-scale positive changes in the Indian Himalayan region (IHR) beyond the pilot scale through active collaboration at the national level and with all the States and Union Territories of the Himalayan region.
4. Mr. Christoph Haemmig, Project Lead, GEOTEST consortium introduced the consortium members and gave a brief overview of Landslide EWS initiative in Uttarakhand under SCA-Himalayas project. He outlined the outcomes, milestones and deliverables of the initiative. Mr. Haemmig explained the conceptual design of a regional scale landslide EWS to be installed at an area with high risks. The precipitation based EWS prototype shall be developed and calibrated together with Indian experts. Existing Automated Weather Stations (AWS) shall be included in the system, combined with additional stations to optimize the data basis, and thus enhance the accuracy of a potential forecast/warning. He emphasized the importance to monitor and document all landslides (within the defined project perimeter) with a detailed event register. He mentioned that as mountainous countries, India, and Switzerland are both affected by climate change and precipitation triggered landslide events.

5. Prof. Markus Stoffel, University of Geneva (UNIGE) focused on the identification of landslide hotspots in the State through spatio-temporal landslide probabilities deriving from landslide density maps and landslide inventory database (1993-2020). In Chinyalisaur Block, areas have been demarcated in different category of landslide risk zones. He explained the precipitation threshold as per lithology and the correlation between annual landslide number for various precipitation trigger mechanisms. 8 ground station data were used for developing a correlation between ERA5 and CHIRPS datasets. While discussing on the validation and improvement of SDC land susceptibility model, it was mentioned that Bayesian Bivariate Statistical Models of UNIGE has a better prediction accuracy of 88% than the Hierarchical Model with 74% accuracy. The susceptibility maps have improved DEM resolution, lithology, updated road maps, lineaments and new LULC maps. A total of 4,025 validated landslides (1993-2020) were studied, out of which 51% are new/natural, 16% are reactivated/enlarged, 22% related to road construction and 11% are flood related. He mentioned that the model was better than expert model prepared earlier and uses random years as training data sets for prediction to reduce bias.
6. Dr. Anna Scolobig, UNIGE discussed the training needs and capacity building involved in the EWS development and operationalization. The process includes, in depth assessment of EWS training, capacity building needs, development of training modules and generic guidelines. The need to develop a people centric EWS inclusive of risk knowledge, monitoring and warning services, dissemination & communication, and response capability. A brief experience of the field visit to Uttarakhand was provided by Dr. Ashok Kumar Singha. The events in the mountains are unexpected but their frequency has increased in the past 10 years with a heavy livelihood impact. The events are not restricted to monsoon season, instead are occurring in dry season as well. Uttarkashi has a total of 18 AWS installed in different locations, and District Disaster Management Authority (DDMA) has a real time road blockage portal. The information flow is both-sided at the time of the event. The DDMA is the key focal point in the district and at village level, it is headed by a local elected PRI member. Dr. Singha explained that the need of strengthening disaster preparedness at community level.
7. A discussion and jam board exercise session were organized on various key issues. Below is the listing of the key issues and a summary of the discussion points for each of the issues:
    a) Dr. Kanungo, CBRI, Roorkee has suggested that all landsides from 1993- 2015 to be considered for validation and further explained the correlation between antecedent conditions (especially the precipitation threshold) and landslides. He pointed out that for better prediction the models may consider a combination of rainfall threshold and lithology along with mechanism of landslide.
    b) Need for a local inventory of dry springs in the State is discussed amongst the Experts.
    c) Dr. Kanungo also suggested to work together on a pilot that they have initiated in Uttarakhand.
    d) Knowledge about the relevant hazard processes, areas of risk, previous studies in the region:
        - EWS at block level will ease the monitoring of given landslide that could be reactivated
        - Prof SP Pradhan mentioned the limitations of regional scale models have limitation as focus should be on a specific landslide area. However, finer data and AWS density should be considering a hotspot for the pilot.
        - The calibration of sensors should consider both climatological and lithological factors (debris slide, rockslide, debris flow). Consideration of inclinometer data (several sensors are installed to capture both online and real-time data) along with local human observatory (to assess the signature) should be useful.
        - Dr. Kanungo has agreed on a collaboration, so that the pre-existing landslide data collected by CBRI may be used by the GEOTEST consortium as well.
        - Dr. Rautela indicated the higher rate of casualty when a new landslide takes place. He also suggested to consider Varunavrat region as another area for pilot.
    e) Capacity and Training Needs:
        - Bottom-up approach from local to district level- Training of the locals

- State Disaster Management Authority can be the ideal trainers, communicating with the local people
- Ms. Ada Lawrence, Sikkim suggested that focus should be on both training and implementation, as there are numerous trainings on landslides where the hill states participate. She focused on use of local low tech tools, like torches, cutters, mobiles phones during response and recovery phase. Ms. Ada shared her experience from Sikkim, where landslide EWS is installed by Amrita University, where data is received from the site and warning is shared with communities at risk through the Sikkim State Disaster Management Authority (SSDMA). 16 Gram Panchayat Units (GPU) are identified in Sikkim and volunteers were trained on basic response rescue equipment's. Emergency Control Room were established in each GPU. A local level control room can be established to help the communities as first responders whilst waiting for external help.
- Dr Ashok Singha, shared experience in use of Ham Radios in case of failure of mobile network.
- Locals to be provided awareness on success stories of EWS for GLOF, so that people get alerted during any event.
- Prof SP Pradhan, IIT Roorkee suggested that the key training elements for locals should capture the pattern to detect the mass movement, safety of sensors, interpretation of the warnings.
- Some other elements should be to identify the safe places during disaster. Dr. PD Mathur from USDMA emphasized on the need to involve the PRI members in the training process and build their capacity. The modules should be practical and delivered by locals after the experts conduct the training of trainers. He also emphasized the call of prime minister to build local response capacity and use of social media as tools for the training.

8. In the concluding remark, Dr. Mustafa Ali Khan summarized the discussions and thanked the participants for taking out their precious time to join the discussion, their active participation and critical contribution in taking the initiative forward.

C Minutes of the meeting to discuss final draft report on training and capacity building needs for EWS in Uttarakhand, Sep 27, 2022

MINUTES OF THE MEETING TO DISCUSS FINAL DRAFT REPORT ON TRAINING AND CAPACITY BUILDING NEEDS FOR EWS IN UTTARAKHAND

Date and Time: 27/09/2022, 01:30 – 02:30 PM

Venue: Virtual mode

Ms. Ridhima Sud, team leader, SCA-Himalayas welcomed all the participants and briefed about the SCA-Himalayas project of Swiss Agency for Development and Cooperation (SDC). She briefed about the Knowledge Briefs on Early Warning System (EWS) training and capacity building needs for landslide risks in the Bhagirati valley in Uttarakhand, as part of Disaster Risk Management Planning and Implementation Support in the Indian Himalayan Region. She said that the analysis in the report addresses topics relevant to the EWS design, implementation, and effectiveness and focuses not only on technical but also on institutional, social and economic capacities and regulatory aspects relevant for the EWS implementation and long-term maintenance.

Ms. Divya Sharma, Deputy Head, SDC welcomed all participants and introduced Geotest led consortium, which is undertaking the development Landslide Early System in Bhagirathi valley and her expectations from the meeting on knowledge briefs.

Ms. Anna Scholobig, Senior Research Associate, Institute of Environment Science, University of Geneva through her presentation discussed the purpose, objectives, methodology and key results of the knowledge brief on EWS in Uttarakhand. She also discussed the gaps between present know-how and required skill sets of different stakeholders on the subject and recommendations on training and capacity building needs for EWS in Uttarakhand.

Dr. Piyoosh Ratula, Executive Director, USDMA. said that report is well prepared and covers all aspects of training and capacity building needs on EWS in Uttarakhand. He further said that warning generation is important but dissemination of warning is as important as generation of warning. He further added that community must be trained to translate warning into action. He stressed upon documenting traditional coping mechanisms and best practices for EWS. It was suggested that best practices on low cost community-based EWS systems is to be annexed with the final knowledge briefs on training and capacity building for EWS

Dr. Anirudh Uniyal, said that most landslides are observed along the road to Gangotri shrine which put the floating population(pilgrims) under threat so warning to floating population has to be taken on priority, to add to it many landslides are hidden slides and cannot be deducted by the common man and these slides have a sudden outbreak with no lead time for warning. He said, landslides are now all season phenomenon and are not restricted to monsoon season only. He further suggested that training modules/curricula must include local hazard scenarios and traditional coping practices.

Dr. Girish Chandra Joshi, Senior Consultant, USDMA told that the state of Uttarakhand has many shadow areas which still lack proper communication, so recommendations on emerging technologies that may be useful to cover these shadow areas would be useful for the state government. Dr. Joshi said a community based low-cost early warning system is the need of the hour. It was suggested to prove recommendations on the communication system to cover shadow areas in the state for warning communication He said the recommendations given through this knowledge brief document on EWS in Uttarakhand would be utilized by the state government for developing EWS training and capacity building programs.

The final report after incorporating suggestions from the participants to be shared with USDMA for endorsement.

D List of the consulted stakeholders

INCEPTION WORKSHOP PARTICIPANTS

1. Ms. Corinne Demenge, Head Swiss Cooperation Office India and Counsellor;
2. Dr. Piyoosh Rautela, ED, USDMA;
3. Maj. Rahul Jugran, ED, Incharge, USDMA;
4. Mr. Panwar Jay, Consultant DDMA, Uttarkashi;
5. Mr. Barendra Sahoo, Consaltant CTRAN;
6. Dr. Perry Bartelt, SLF;
7. Dr. Bikram Singh, Director, IMD Dehradun;
8. Mr. Sharda Gusain, Engineer, DDMA, Uttarkashi;
9. Mr. Praveen Kush, EE PWD Uttarkashi;
10. Dr. Girish Chandra Joshi (USDMA), Senior Consultant, USDMA;
11. Mr. H K Pande, GM, TRM, Jal Sansthan, Uttarakhand;
12. Mr. Mohammed Gulfishan, GM, Bhagirathi Valley, UJVN Limited;
13. Ms. Ishani Mohanty, Consultant CTRAN;
14. Ms. Tripti Jayal, Research Associate, EPCC Directorate, Uttarakhand;
15. Mr. Manoj Kaistha (GSI), Director, GSI Dehradun;
16. Dr. Debi Prasad Kanungo, (Chief Scientist & Group Leader, Geo-Hazard Risk Reduction Group, CSIR-CBRI, Roorkee);
17. Mr. Sushil Khanduri, Geologist, USDMA;
18. Mr. Keshav Koirala, Sikkim SDMA;
19. Mr. Anil Kumal, Joint Director, DGM, Dehradun;
20. Mr. Ajay Kumar, Sr. Manager(G&G), THDCIndia Ltd;
21. Ms. Pallavi Kumari, Executive Engineer, Payjal Nigam, Dehradun;
22. Dr. P.D. Mathur, Sr Consultant, USDMA;
23. Mr. Minish Shankar Sant, AE, IRI, Roorkee;
24. Ms. Neetu Tyagi, Research Associate, EPCC Directorate, Uttarakhand;
25. Mr. B.S. Dogra, Jal Nigam Uttarkashi;
26. Mr. Chandrakanta Ojas -Indian Institute of Soil and Water Conservation (IISWC)), ICAR-IISWC;
27. Dr. S.P.Pradhan, Dept of Earth Sciences, IIT Roorkee;
28. Ms. Protusha Biswas, Consultant CTRN;
29. Mr. Sita Ram, EE FIU, Peyjal Nigam, Dehradun;
30. Mr. D S Kutiyal, Sr Staff Officer - Planning, PWD, Dehradun;
31. Ms. Kanchan Rawat, Engineer, Uttarakhand Peyjal Nigam;

32. Mr. Mukesh Singh, SRF, EPCC Directorate, Uttarakhand;
33. Mr. Rohit Thapliyal (Sc-C), Scientist, IMD, Dehradun;
34. Mr. Vipan Mandwal, SRF, EPCC Directorate, Uttarakhand;
35. Dr. Maneesh Semwal, Senior Geologist, UDRP;
36. Dr. Ashok Singha, CTARN;
37. Ms. Divya Sharma, Thematic Advisor, SDC;
38. Ms. Ada Lawrence, Technical Expert, DRM, SCA-Himalayas Sikkim;
39. Dr. Mustafa Ali Khan, Team Leader SCA-Himalayas;
40. Mr. Bhupendra Bhaisora, Technical Expert, DRM, SCA-Himalayas;
41. Mr. Suresh Betapudi, Sector Lead, DRM, SCA-Himalayas;

ONLINE MEETING FOR KNOWLEDGE BRIEF

1. Mr. Bhupendra Bhaisora, Technical Expert, SCA-Himalayas;
2. Ms. Divya Sharma, Deputy Head of Cooperation, SDC India;
3. Dr. Girish Joshi, Senior Consultant, USDMA;
4. Dr. Sweta;
5. Ms. Fatima Amin,Young Professional, NIDM;
6. Dr. Piyoosh Rautela, Executive Director, Uttarakhand State Disaster Management Authority, Uttarakhand;
7. Ms. Ridhima Sud, team leader, SCA-Himalayas, SDC India;
8. Mr. Suresh Betapudi, Sr Expert – SCA-Himalayas (PIU);
9. Dr. Anirudh Uniyal, Scientist & Head Earth Resources Division, Technical Secretary to Director & Scientific Adviser to Chairman G.B., Remote Sensing Applications Centre UP
10. Ms. Akshara Saini, Manager, Finance and Administration, SCA-Himalayas;

INTERVIEWEES

1. Mr. Anil Rana, Village Netala, Uttarkashi;
2. Mr. Bimeleshwar Prasad Bhatt, Village Siror, Uttarkashi;
3. Mr. Anil Saklani, Village Dunda, Uttarkashi;
4. Mr. Rahul Jugran, Incharge, State Emergency Operation Centre, Uttarakhand;
5. Mr. Devendra Patwal, DDMO, Uttarkashi;
6. Mr. Shardul Gusian, Consultant DDMA, Uttarkashi;
7. Mr. Nathi Singh Chauhan, Village Pata, Uttarkashi;
8. Dr. Piyoosh Rautela, ED USDMA;

E Examples of Monitoring and Early Warning Systems – Best Practice

Here below the links to on-line portals/practitioners networks that include constantly updated early warning system best practices:

- ☐ **Adaptation at Altitude**
- ☐ **PANORAMA**
- ☐ **LandAware**
- ☐ **Climate ADAPT**

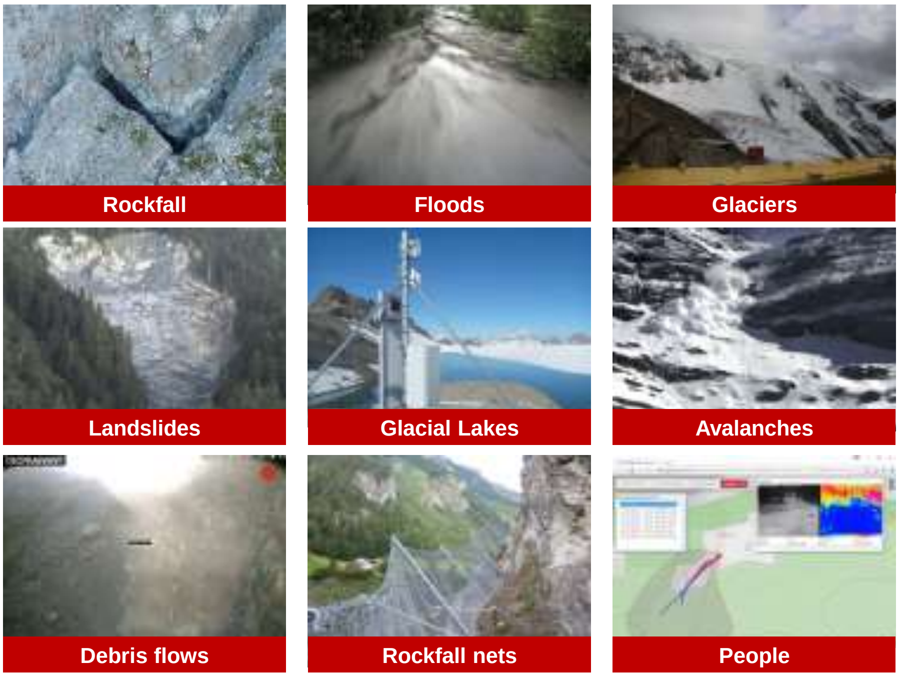
Please also find in the following a compilation of best practice EWS systems (and some theoretical information):

Disaster Risk Management Planning and Implementation Support in the Indian Himalayan region

Examples of Monitoring and Early Warning Systems – Best Practice

1

Process Understanding: What and where to monitor?

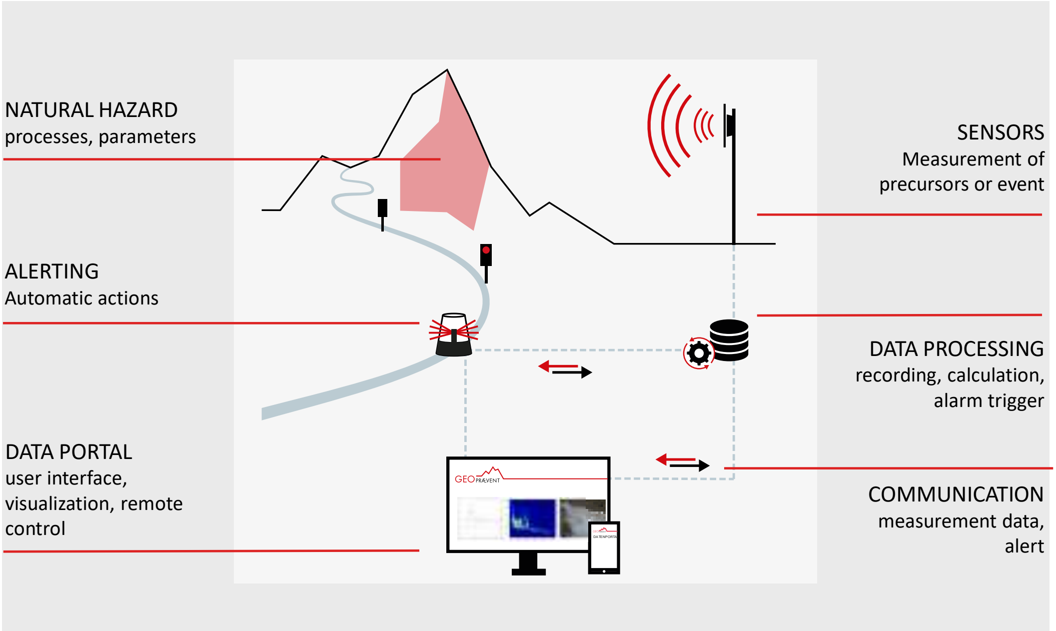


All photos are from operational GEOPRAEVENT installations.

2

2

Early Warning System Setup

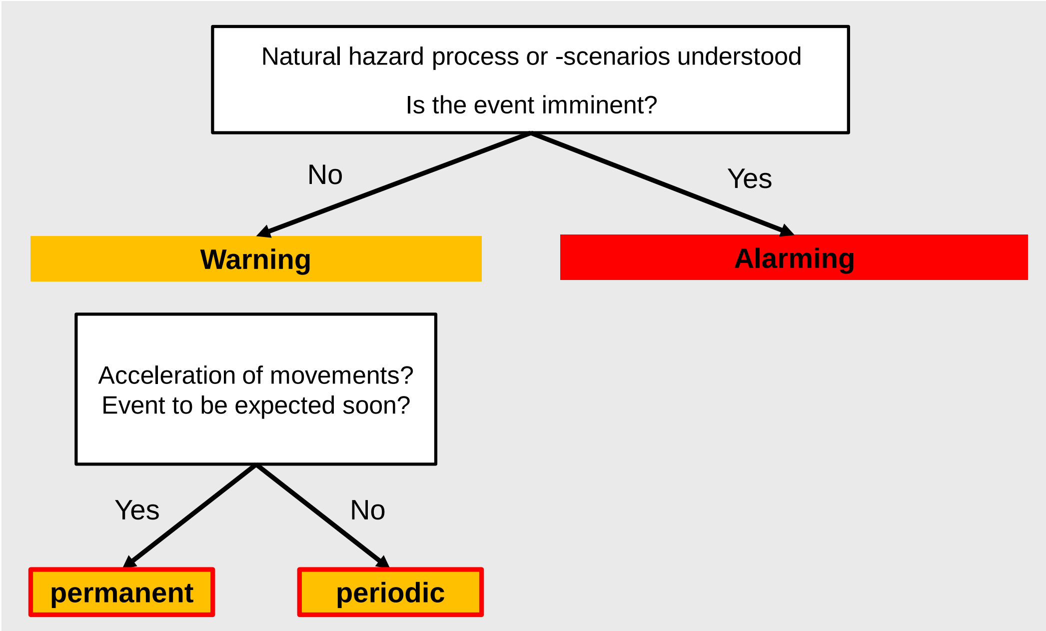


Early Warning System Setup

Automatic measures, e.g. road closures, evacuation of residents/construction sites

- Traffic lights/barriers for roads with display for information
- Sirens for construction sites and inhabited areas
- Radios with earphones for noisy environments, e.g. in the excavator
- Functionality must be monitored (automated or by regular test alarms)

Difference between Warning and Alarming



Alarming versus Warning

	A **Alarm system**	W **Warning system**
	measures actual event	measures event precursors
Measurement	• velocity • pressure • water level • deformation	• precipitation • snow depth • water level • deformation • temperature
Action	direct and automatic alerting	Interpretation of data by experts. Automatic model integration individual cases

Reliability of EWS

Different requirements for

Reliability
«How well does the system fulfil its function?»

Availability
«How often is the system out of service?»

Maintainability
«How expensive are maintenance and repairs?»

Security
«How safe is the system?»

For example, for

- applied sensors, redundancy
- data transfer
- evaluation algorithms
- alerting
- ...

7

7

Example of Sensors

Detection of slow movements / Deformation measurements

- Telejoint-/Extensometer
- Tachymeter/Total Station
- GNSS (GPS)
- Laser scanning
- Image analysis
- Interferometric Radar

Usually
Warning system

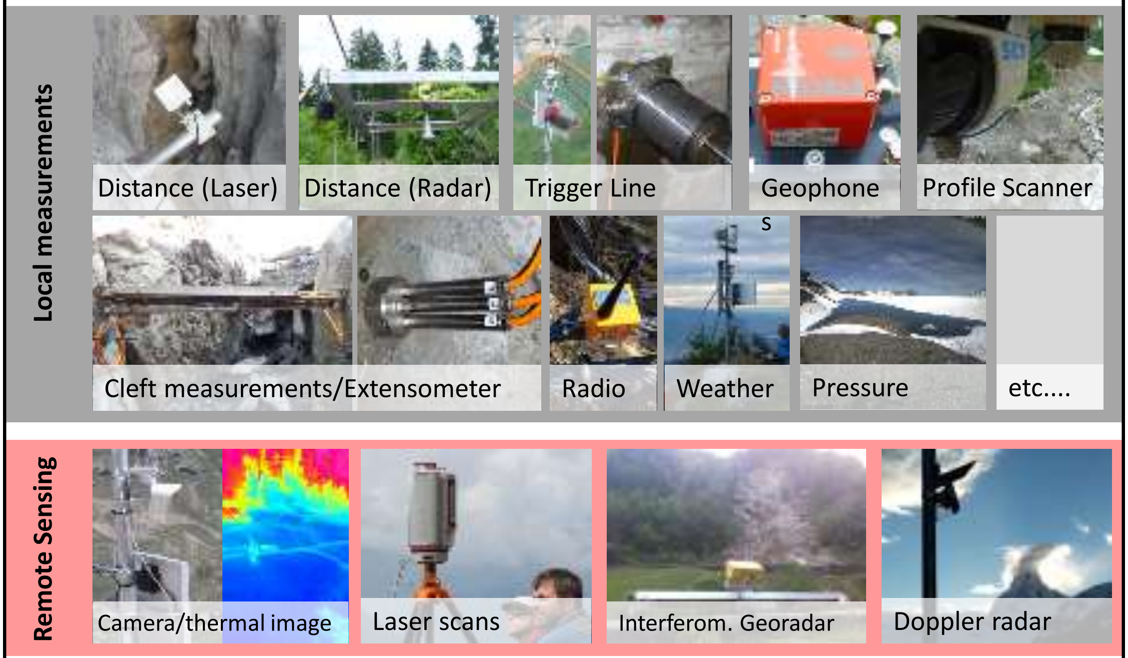
Detection of fast mass movements

- Trigger lines
- Level measurements
- Geophones
- Doppler radars

Usually
Alarm system

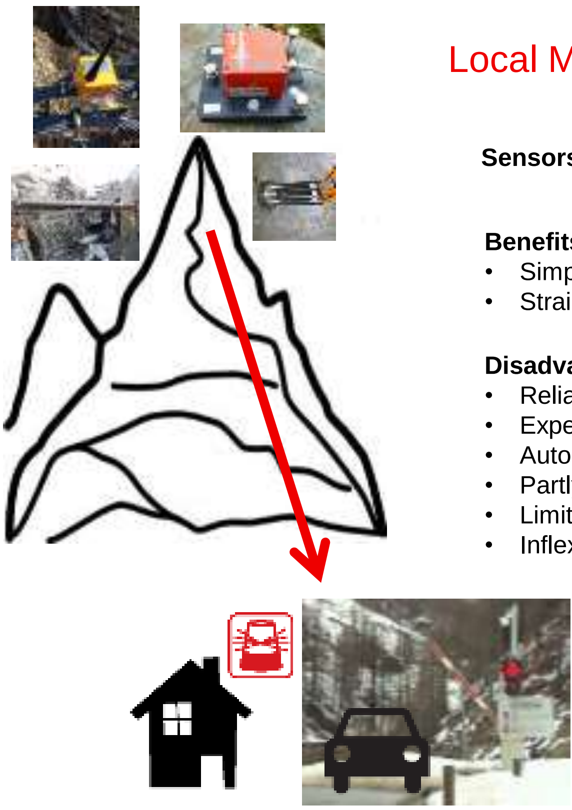
8

Local Measurements versus Remote Sensing



All photos are from operational GEOPRAEVENT installations.

Local Monitoring System: Examples



Sensors on the mountain – alerting in the valley

Benefits
- Simple, inexpensive sensors
- Straightforward algorithms/threshold values

Disadvantages
- Reliable data transmission required
- Expensive, dangerous installation
- Autonomous power supply
- Partly high maintenance costs
- Limited measuring range
- Inflexible if danger changes

Rock Instability: Telejoint-/Extensometer

Deformation measurement

Extensive?	No
Remote measurement?	No
All weather?	Yes
Accuracy	Sub-mm
Costs	Low (# of sites)

Example
Tafers, Galterengraben, Switzerland
Prediction break-off approx. 2500 m^3
Total deformation before break-off: approx. 20 mm

Landslide/Rock Instability: Tachymeter/Total Station

Deformation measurement

Extensive?	No
Remote measurement?	No
All weather?	No
Accuracy	a few mm
Costs	low

Example
Gurtnellen, Rockfall SBB, Switzerland
redundant measuring setup with approx. 50 mirrors
10 telejointmeters, 5 extensometers, trigger lines, interferom. Georadar, local alerting

Landslide Monitoring: GNSS (GPS)

Deformation measurement

Extensive?	No
Remote measurement?	No
All weather?	Yes
Accuracy	Some mm to cm
Costs	Medium-High

Example
Landslide Malbun, Principality of Liechtenstein
3 GPS + 1 reference station. approx. 1 cm/day
Several predefined threshold for Sms

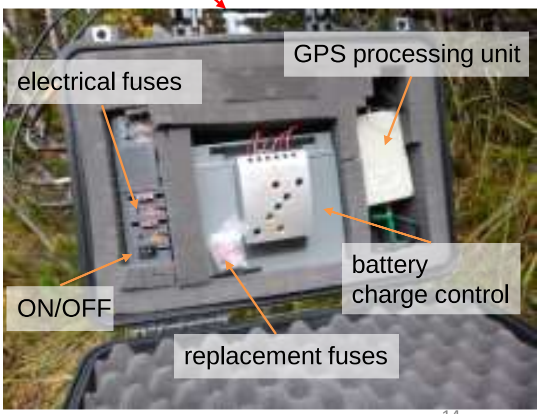
Landslide Monitoring: GNSS (GPS)

antennas (GPS/GSM)

solar panel

control electronics

Points to keep an eye on:
- solar panels (damage,…)
- trees above station
- stability of poles



Debris Flow/Flash Flood: Trigger lines

Fast mass movement
Costs low

Example
Bondo, Val Bondasca, Switzerland
3 trigger lines close the road

Force measurement

Safety switch

Predetermined breaking point

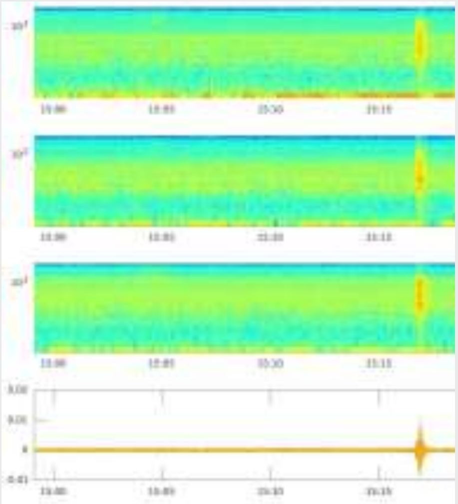
Water level measurement (discharge/lake level)

Fast mass movement
Costs Low-Medium

Example
China, Hekou, Kelequin River monitoring
2 gauge radars, 2 cams, weather station

Debris Flow: Seismics/Geophone

Fast mass movement
Costs medium



Example
Val Bondasca, Switzerland
debris flow alarm system
3 seismometers redundant to 2 gauge radars

Frequency response and time sequence of multiple sensors allows for classification of events

Example:
- M 2.5 Earthquake in Ticino at a distance of 80 km

Precipitation Measurement (Automatic Weather Station)

Weather stations for landslide monitoring

→Identify elevated landslide risk

- Temperature
- Humidity
- Precipitation
- Soil moisture
- Wind

Lora sensors

Precipitation Measurement (Automatic Weather Station)

Precipitation measurement and accumulated rainfall over 24h, 3d, 14d

Automatic notification possible via SMS and/or email when threshold is exceeded

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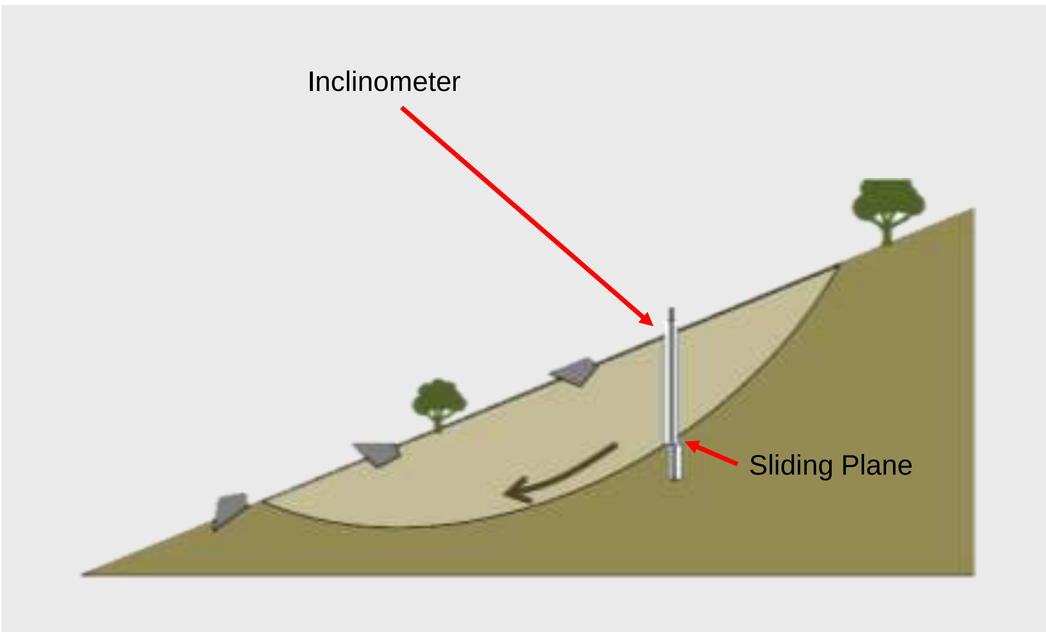
Landslide Monitroing: Inclinometer



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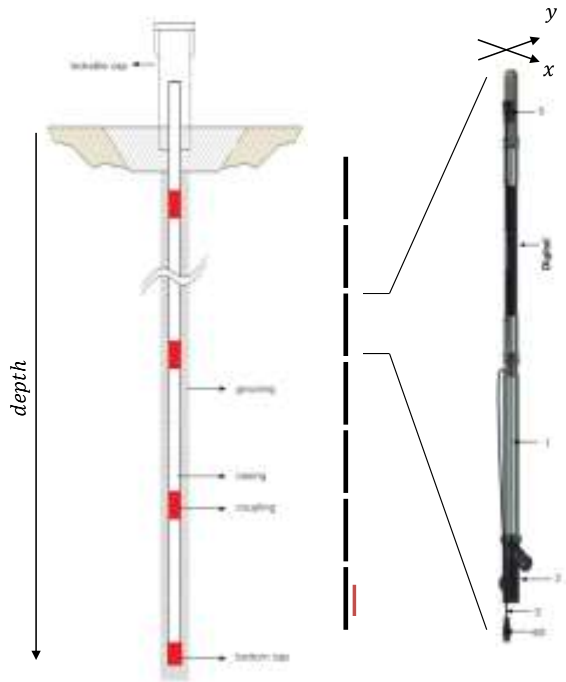
Inclinometers – Basics



tilt angle α and temperature T:

$$[\alpha_x, \alpha_y; T] = f(depth)$$

x-direction in direction of the slope
y-direction perpendicular to slope

1. A differential MEMS sensor housed in a waterproof stainless steel body. The sensor could be mono or biaxial. Temperature can be read in both models;
2. wheels assembly to slide along the grooves of the inclinometer casing;
3. electrical cable for the connection to the readout. A male/female connectors are assembled on the digital BH-Profile cable (5);
4. only for digital version: termination resistor (last BH-Profile of chain).

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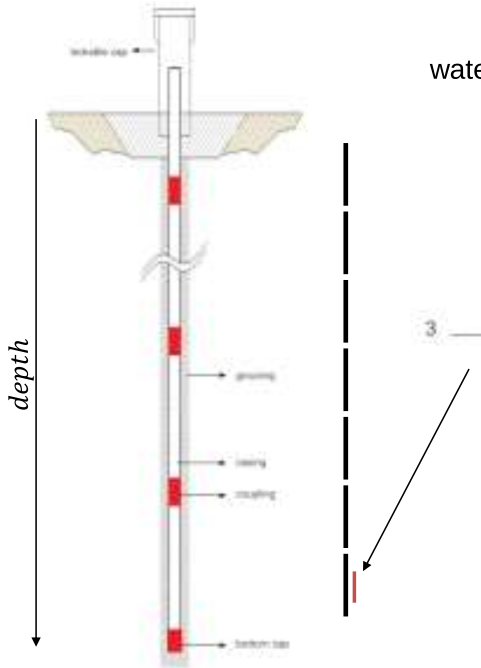
Automatic Inclinometers



water pressure

Electrical piezometer consists in:

1. Stainless steel cylindrical body
2. Hydraulic chamber
3. Filter holder and filter
4. Measuring sensor (membrane)
5. Thermistor (only with VW type)
6. Electric cable for the connection with the readout

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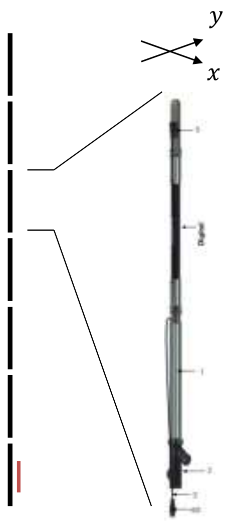
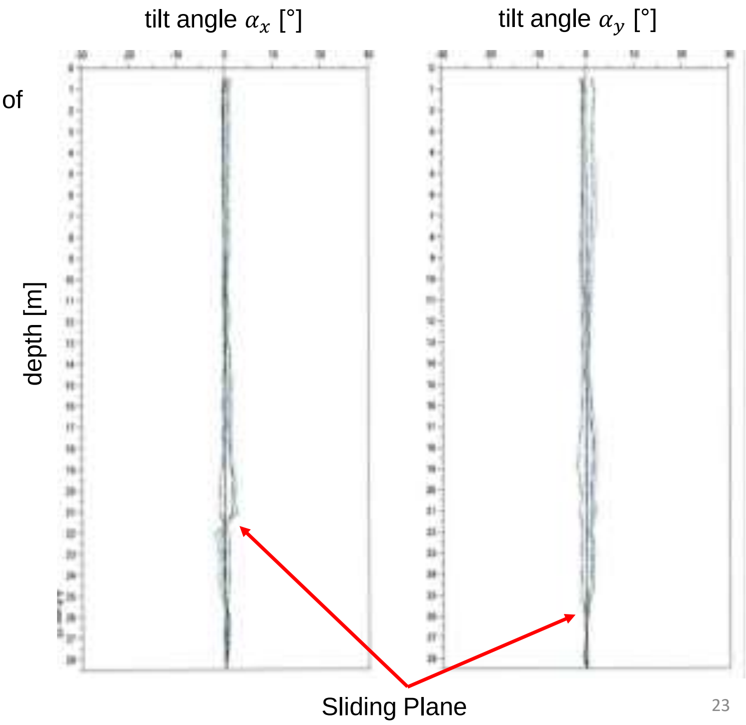
Inclinometers – Data Interpretation

tilt angle as a function of depth





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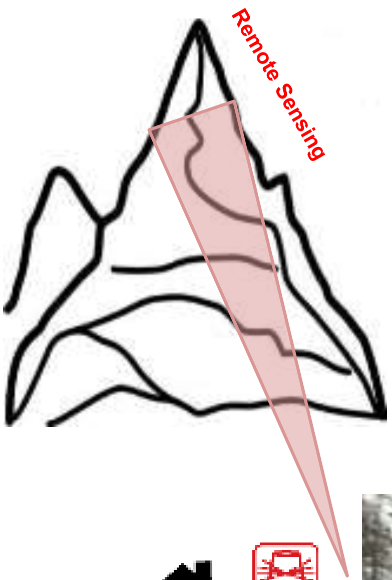
Remote Monitoring Systems: Examples



Sensors in the valley – alerting in the valley

Benefits
- Large and flexible coverage area
- Simple, safe installation
- Cheaper (at least per monitored m^2)
- Smooth data/alarm transmission

Disadvantages
- Visibility not always guaranteed
- In extreme cases disturbances due to weather

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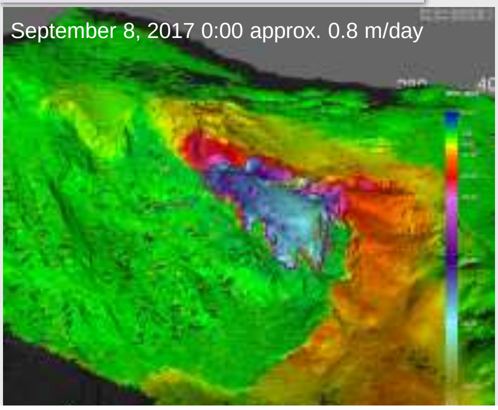
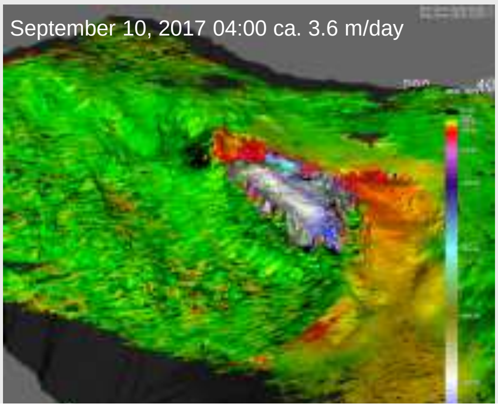
Interferometric Georadar

Deformation measurement

Extensive?	Yes
Remote measurement?	Yes
All weather?	Yes
Accuracy	Sub-mm to mm
Costs	Medium to high

Example
Saas Grund, Trift Glacier/Weissmies, Switzerland
Glacier collapse approx. 300'000 m^3





- Range up to 4km
- Spatial resolution of 1mrad, i.e. 4m pixel width at a distance of 1 km
- Suitable for alpine environments, autonomous power supply
- Measure 2-D deformation vectors

Interferometric Georadar

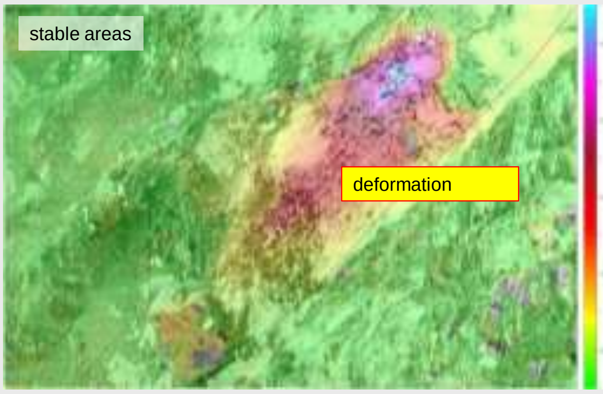
Deformation Camera: Image analysis

Deformation measurement

Extensive?	Yes
Remote measurement?	Yes
All weather?	No
Accuracy	Some cm
Costs	Low to Medium

Example
Saas Grund, Trift Glacier/Weissmies, Switzerland
Glacier collapse approx. 300'000 m^3 on 10.09.2017

- Cost-efficient monitoring solution with large area coverage
- Automatic image selection and processing with sophisticated algorithms
- Colour display of movements including direction of displacement



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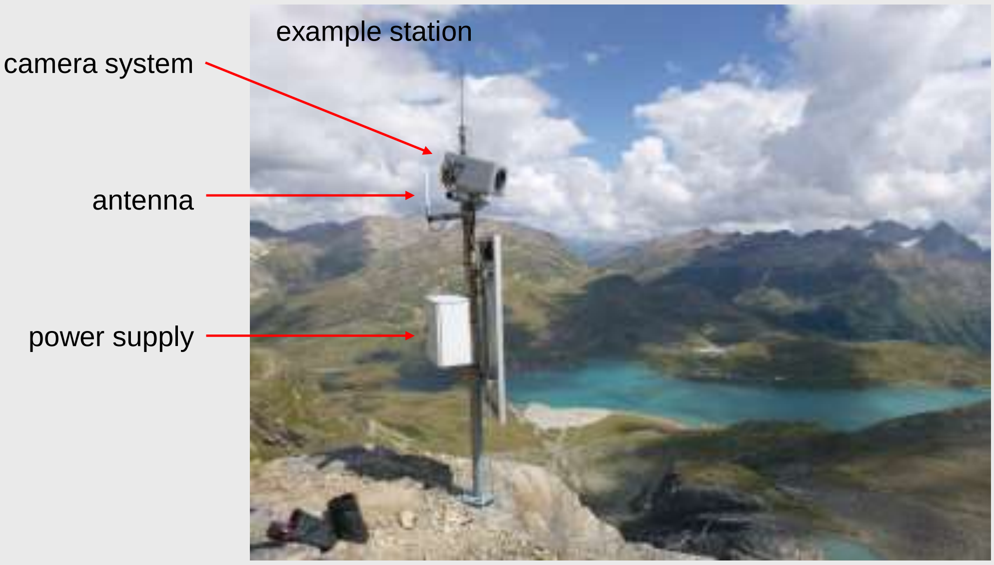
Deformation Camera



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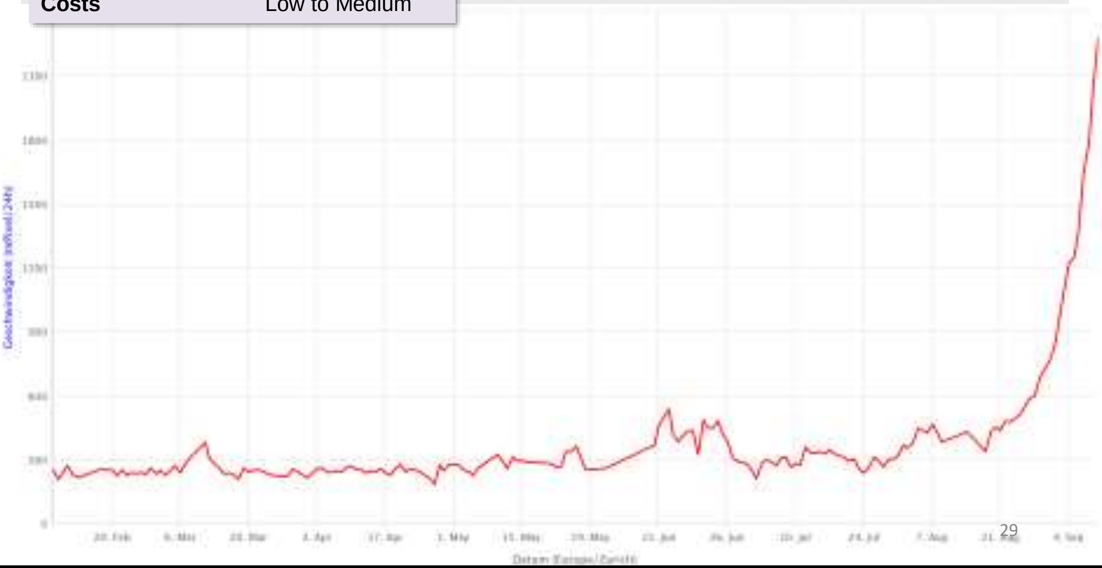
Deformation Camera: Image analysis

Deformation measurement

Extensive?	Yes
Remote measurement?	Yes
All weather?	No
Accuracy	Some cm
Costs	Low to Medium

Example
Saas Grund, Trift Glacier/Weissmies, Switzerland
Glacier collapse approx. 300'000 m³

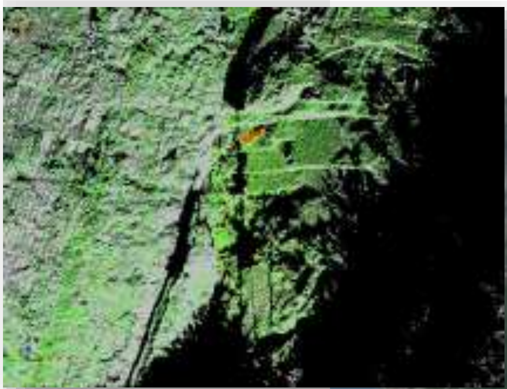


Large Scale Rock Movements/Landslide: Laser scanning

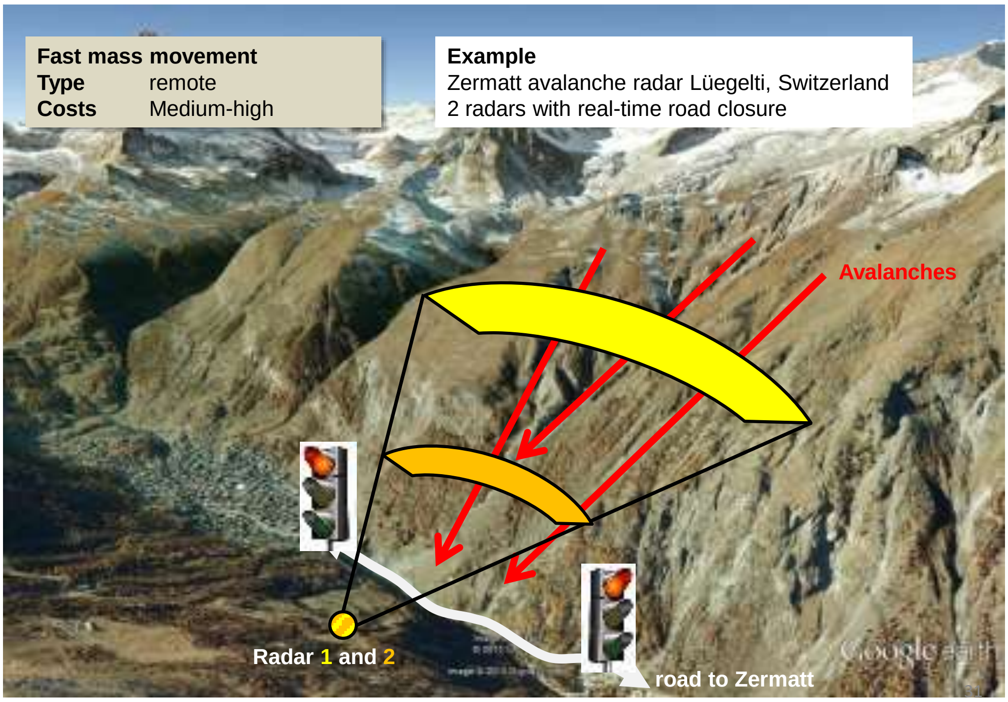
Deformation measurement

Extensive?	Yes
Remote measurement?	Yes
All weather?	No
Accuracy	Some cm
Costs	Medium

Example
Several rock faces SBB Gotthard, Switzerland
Annual measurements with laser scan (a few cm) and Interferometric Georadar (a few mm)



Doppler radars



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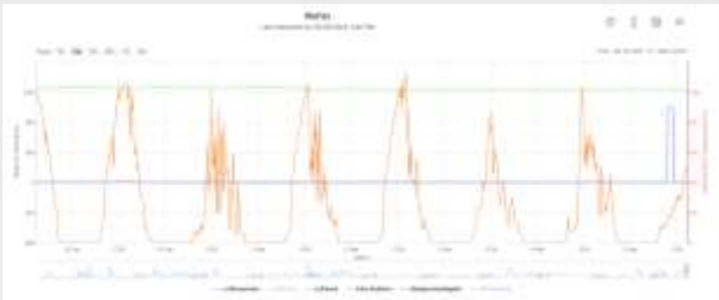
Online Data Portal

- individual views
- setup of automatic notifications
- Danger level map possible



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